# FISSION PRODUCT GAMMA ACTIVITY IN SURFACE AIR—80th MERIDIAN AND U.S. LOCATIONS, DECEMBER 1964[1]

*Health and Safety Laboratory, Atomic Energy Commission*

Since January 1, 1963, surface air filter samples have been collected as part of the HASL (Health and Safety Laboratory) 80th Meridian Network (figure 1). This network consists of fourteen air sampling stations near the 80th Meridian (West) from Thule, Greenland, to Punta Arenas, Chile. An additional station at Mauna Loa, Hawaii, is included for comparison of data with the Chacaltaya, Bolivia station. These stations are both at high elevations and are at approximately equal north and south latitudes, respectively.

In August 1963, six additional air sampling stations were added to the HASL Network in North America (*1*). As with the original 80th Meridian Network sampling stations, both air filter and deposition samples are collected. Where surface air data are reported on a monthly basis, the deposition data are reported quarterly.

## *Sampling and analytical procedures*

Air particulates are sampled on 8-inch-diameter polystyrene (Microsorban) filters, drawing air through the filters continuously at the rate of about 1,400 cubic meters per day. Filters are changed on the 1st, 8th, 15th, and 22nd of each month and forwarded to HASL for analysis. A total gamma count over the energy range, 0–3 Mev, is made approximately two weeks after the end of the sampling period, using an 8 x 4-inch sodium iodide (thallium-activated) crystal. The filters are then composited on a monthly basis and analyzed radiochemically, together with monthly ground deposition samples taken at the same site, for detectable fission and neutron activation products.

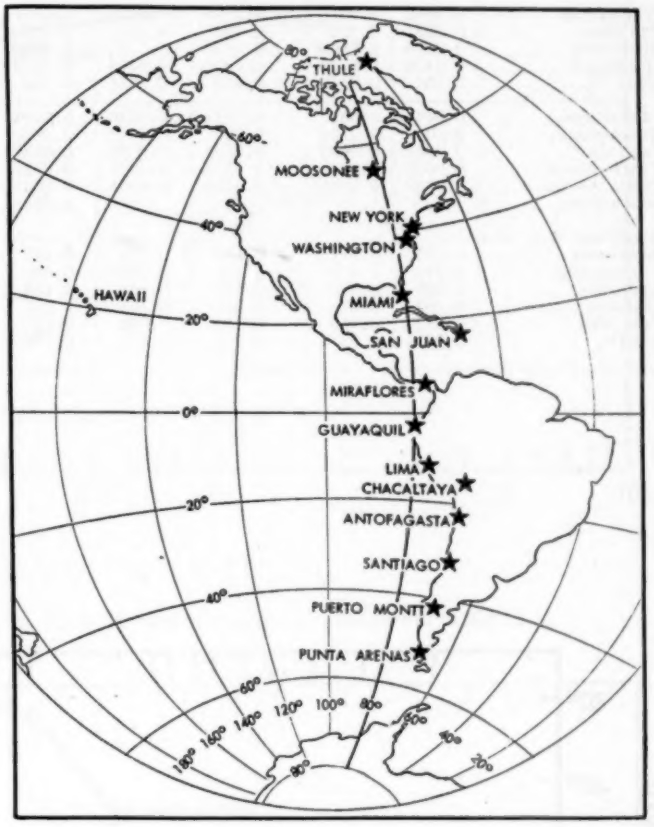


**Figure 1. 80th Meridian Network sampling stations**

## *Results and discussion*

The total gamma activity concentrations in weekly ground level air samples collected during December 1964 by the HASL Ground Level Air Sampling Program are presented in table 1. The average monthly concentrations, weighted by the volume of air sampled during each week, are given in column six. These results are plotted in figure 2 as an activity latitude profile. The Amundsen-Scott South Pole station has been added to the list of sampling sites. This station, maintained by the U.S. Weather Bureau, collects daily samples on 2.5-inch diameter filter paper. These filters are composited on a monthly basis and assayed on an 8 x 4-inch NaI (Tl) crystal. For comparison, the latitude profiles of November 1964 and December 1963 are plotted in figures 3 and 4.

[1] This report was developed from information and data in the April 1965 monthly report entitled "80th Meridian Network, Results of Air Sampling Measurements." These reports are furnished by the Health and Safety Laboratory, AEC, New York, N.Y. 10014.

**Table 1. Radioactivity of surface air, December 1964**

| Sampling site | Gamma activity in photons /min.m³ | | | | |
|---|---|---|---|---|---|
| | 1–8 | 8–15 | 15–22 | 22–1/1/65 | Average |
| Thule | 0.227 | 0.241 | 0.172 | 0.152 | 0.192 |
| Moosonee | 0.114 | 0.091 | 0.144 | 0.114 | 0.116 |
| New York | 0.153 | 0.140 | 0.187 | 0.133 | 0.152 |
| Washington | 0.195 | 0.133 | 0.153 | 0.104 | 0.142 |
| Miami | 0.272 | 0.246 | 0.277 | 0.235 | 0.255 |
| Mauna Loa | 0.0902 | 0.0455 | No sample | 0.0820 | 0.0737 |
| San Juan | 0.108 | 0.128 | 0.155 | 0.159 | 0.139 |
| Miraflores | 0.0470 | 0.0809 | 0.0886 | 0.117 | 0.0866 |
| Guayaquil | 0.0476 | 0.0702 | 0.0603 | 0.0468 | 0.0553 |
| Lima | 0.156 | 0.0658 | 0.251 | 0.0851 | 0.136 |
| Chacaltaya | 0.0404 | 0.023 | 0.0811 | 0.0236 | 0.0404 |
| Antofagasta | 0.101 | 0.0796 | 0.100 | 0.0612 | 0.0853 |
| Santiago | 0.0863 | 0.0908 | 0.0852 | 0.0603 | 0.0787 |
| Puerto Montt | 0.0653 | 0.0295 | 0.0616 | 0.0677 | 0.0522 |
| Punta Arenas | 0.0300 | 0.0366 | 0.0732 | 0.0564 | 0.0505 |
| South Pole | | | | | 0.0452 |
| *Additional U.S. sites:* | | | | | |
| Westwood | 0.135 | 0.177 | 0.182 | 0.148 | 0.143 |
| Chattanooga | 0.210 | 0.155 | 0.149 | 0.0943 | 0.150 |
| Appleton | 0.160 | 0.099 | 0.166 | 0.164 | 0.148 |
| Midwest City | 0.169 | 0.226 | 0.249 | 0.191 | 0.207 |
| Palo Alto | 0.182 | 0.135 | 0.141 | 0.056 | 0.120 |
| Seattle | 0.0552 | 0.0814 | 0.202 | 0.103 | 0.109 |

The December 1964 profile in the Northern Hemisphere follows the pattern of the December 1963 profile almost exactly, but at much lower concentrations. This indicates that the general structure of these profiles is meteorologically significant, being perpetuated from year to year. The November 1964 profile has higher concentrations than the December 1964 profile; its peak at Appleton (44°15'N) is more pronounced, and there is a slight northward shift of the second peak to Chattanooga (35°03'N). These effects may be the result of the debris from the October 16, 1964 Chinese test which was evident in November 1964 samples, but absent in the December 1964 samples. There are other meteorological parameters operative, however, since the concentration at Miraflores was higher in December than in November, and this difference cannot be attributed to the presence of Chinese debris.

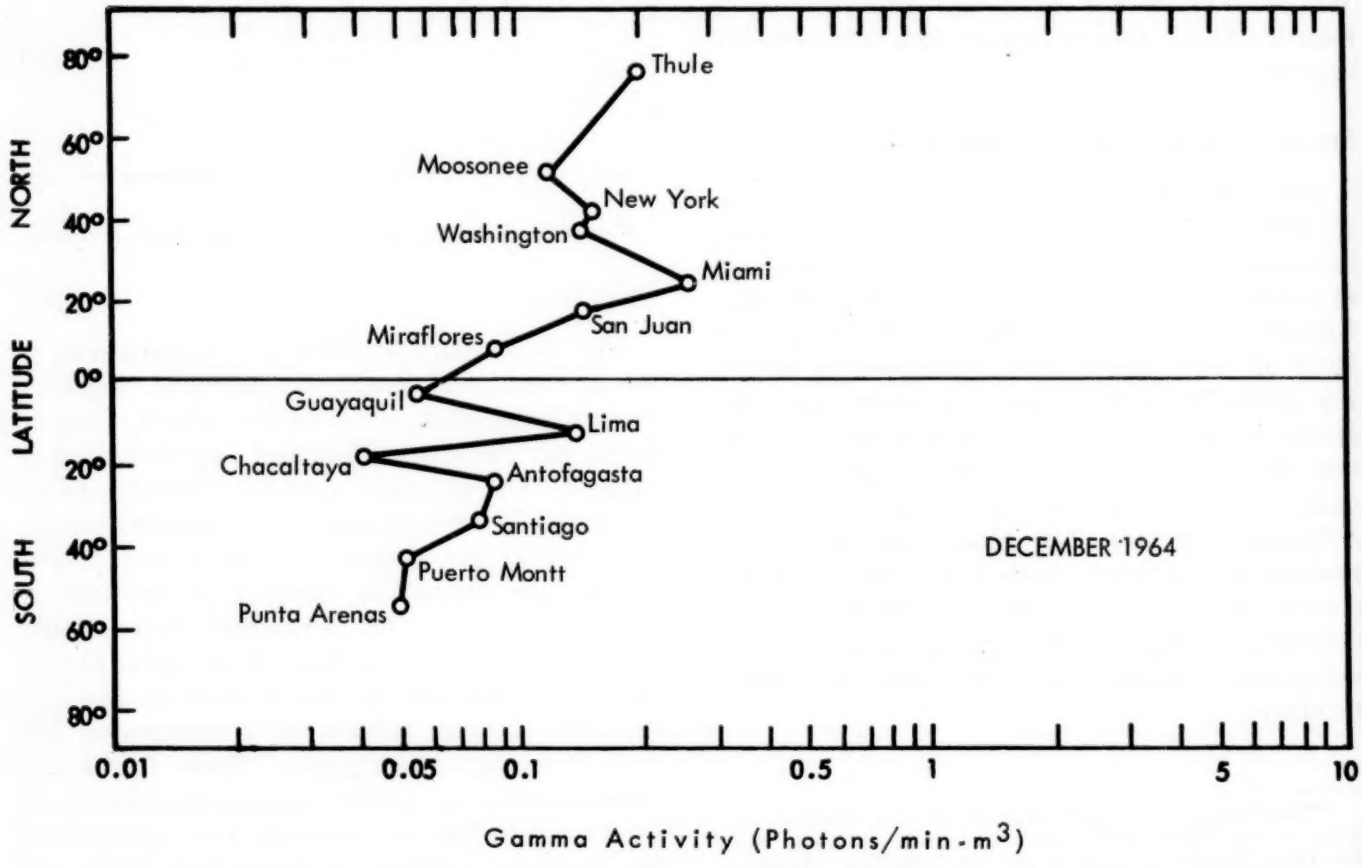


**Figure 2. Profile of surface air gamma activity, 80th Meridian stations, December 1964**

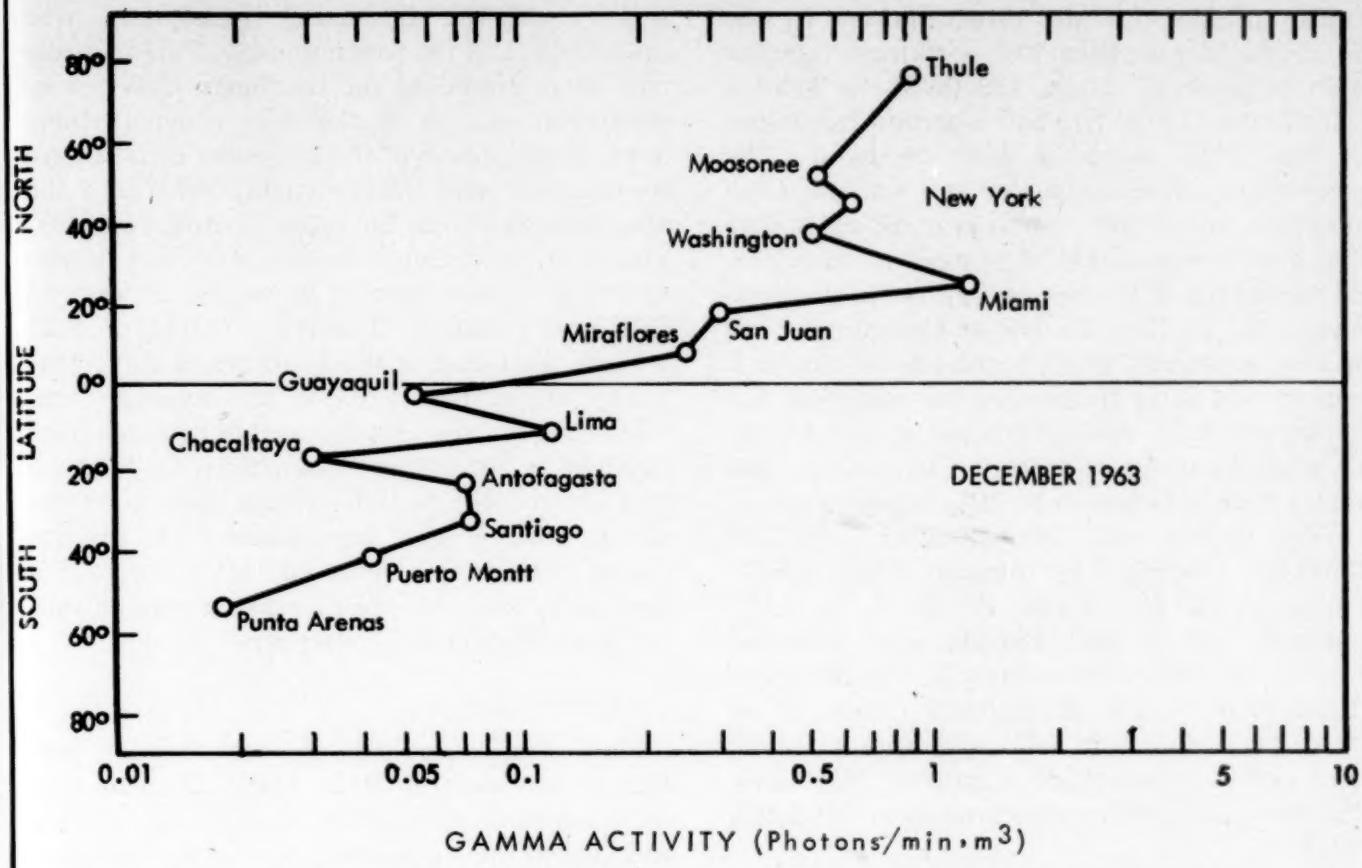


**Figure 3. Profile of surface air gamma activity, 80th Meridian stations, December 1963**

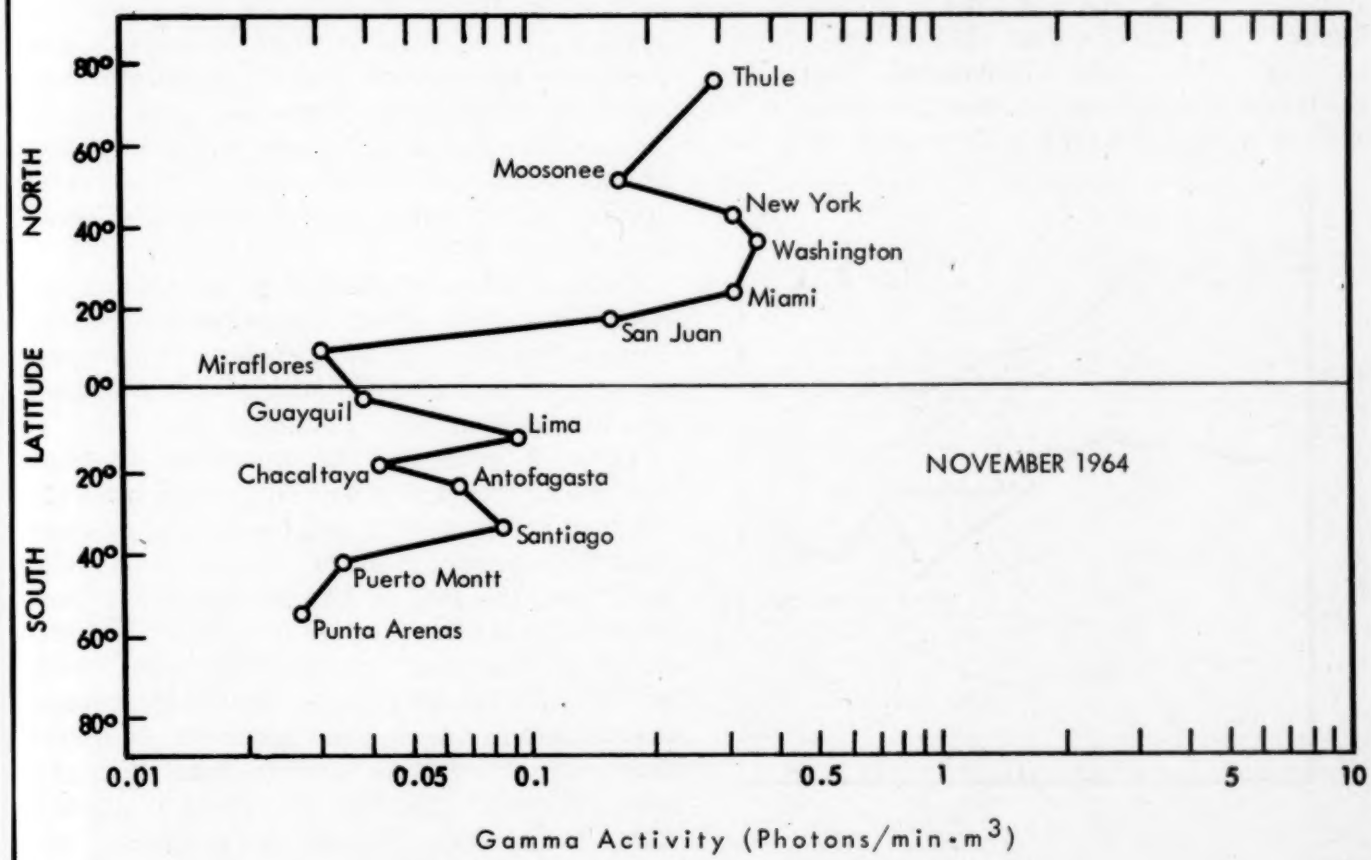


**Figure 4. Profile of surface air gamma activity, 80th Meridian stations, November 1964**

The profiles for all three months in the Southern Hemisphere are strikingly similar with a peak at Lima (12°06'S), a low at Chacaltaya (16°21'S), and a second maximum in the 23°S to 34°S latitude band. The persistence of these peaks and valleys from month to month and year to year indicates that they are the result of local or zonal meteorological conditions. It has been suggested in previous reports (*2, 3*) that the low at Chacaltaya may be the result of the high altitude of this collection site. It is interesting to note that the December 1964 concentrations at practically all stations in the Southern Hemisphere are higher than in the other profiles represented.

The weekly air concentrations in the Northern Hemisphere ranged from 0.0470 $\gamma/min \cdot m^3$ at Miraflores, P. C. Z. to 0.277 $\gamma/min \cdot m^3$ at Miami, Florida and averaged 0.152 $\gamma/min \cdot m^3$. The values in the Southern Hemisphere ranged from 0.023 $\gamma/min \cdot m^3$ at Chacaltaya, Bolivia to 0.251 $\gamma/min \cdot m^3$ at Lima, Peru and averaged 0.067 $\gamma/min \cdot m^3$ (including the average monthly concentration at the South Pole).

A comparative plot of the monthly average concentrations for the Northern and Southern Hemispheres in 1963 and 1964 is presented in figure 5. It appears that all vestiges of the Chinese debris had disappeared from the Northern Hemisphere by December 1964. It is evident in figure 5 that in December 1964 the activity of the Southern Hemisphere was greater than in the previous year. This increase had been predicted on the basis that trans-equatorial mixing of the high concentrations in the stratosphere of the Northern Hemisphere would occur with the low concentrations of the stratosphere in the Southern Hemisphere (*3*). The average activity in the Northern Hemisphere has concurrently decreased so that in December 1964 it is only a factor of 2.25 greater than that of the Southern Hemisphere.

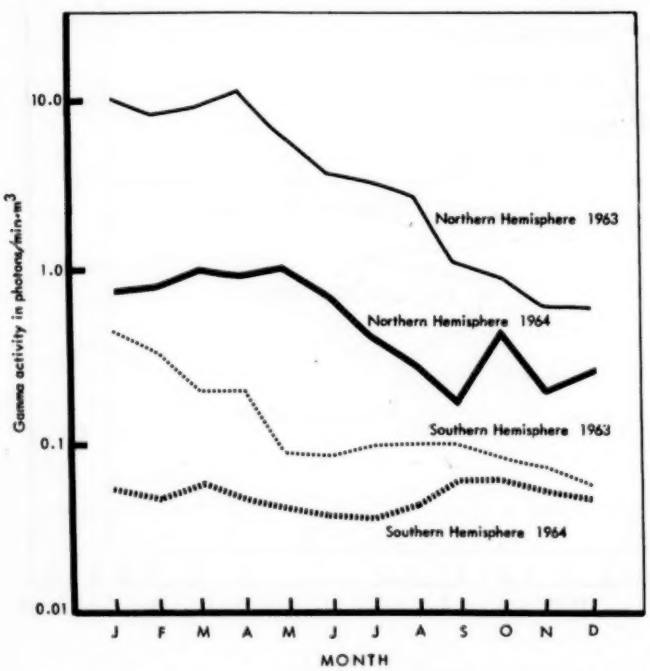


**Figure 5. Average hemispheric gamma activity concentrations for 1963 and 1964**

The slight reduction of the average concentration in the Southern Hemisphere from October to November 1964 shown in figure 5 was interpreted to indicate the decline of the spring peak in that hemisphere (*4*). The increase in December reversed that trend, and is further evidence of the increasing rate of fallout in the Southern Hemisphere.

*Longitudinal effects*

Most of the sampling sites of the Naval Research Laboratory 80th Meridian Program extended along the west coast of South America and along the east coast of North America. In August 1964 six additional sites within the continental United States were instituted as part of the HASL Surface Air Sampling Program to afford better latitude coverage in the Northern Hemisphere and to investigate the effects of the opposite coastal locations in each hemisphere. The data for one year's operation of this network in the absence of atmospheric nuclear testing can now be reviewed with these objectives in mind.

Cesium–137 was selected as the nuclide for study to permit direct comparison with the British Program, which included the determination of cesium–137 among other fission products and induced radionuclides.

Table 2 presents the quarterly average cesium–137 concentrations in ground level air for each of the seasons and the annual average from September 1963 to August 1964. The data from the British Ground Level Air Program (*5*) are also included in table 2 for additional comparisons of sampling sites with widely different longitudes. Quarterly average concentrations were considered to minimize short term variations and to maximize any seasonal effects. The New York and Westwood sites have very similar geographical coordinates, and can be considered essentially as

duplicate stations. The agreement of the data from these two stations in table 2 attests to the good precision of replicate collections and analyses. The data from the New York and Westwood stations are averaged and plotted as a single point in subsequent figures.

The average quarterly cesium–137 concentrations are grouped in longitude bands and are plotted as a function of latitude for each of the four seasons in figures 6 through 9. In each figure, a line is drawn through the points in the 65°W to 89°W longitude band within which all of the original 80th Meridian stations fall, plus three of the six stations which were initiated in August 1963. Figure 6 illustrates that the 1963 fall latitude profile in the Northern Hemisphere was virtually the same for all longitudes. It would be desirable to compare cesium–137 concentrations at stations of different longitudes in the Southern Hemisphere also. Unfortunately, there are no suitable data available for comparison at the present time. The profiles in the Southern Hemisphere are presented in figures 6 through

**Table 2. $^{137}Cs$ concentrations in ground level air, September 1963–August 1964**

| Sampling site | $^{137}Cs$ dpm/100 m³ | | | | | | Annual avg. |
|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | 9/63–11/63 | 12/63–2/64 | 3/64–5/64 | 6/64–8/64 | 9/63–8/64 |
| Thule | 76°36′N | 68°35′W | 6.3 | 7.2 | 13 | 11 | 9.4 |
| Lerwick [a] | 60° N | 01° W | 5.7 | 9.8 | 14 | 9.2 | 9.7 |
| Eskdalemuir [a] | 55° N | 03° W | 8.2 | 5.7 | 8.4 | 6.2 | 7.1 |
| Orfordness [a] | 52° N | 01°30′E | 8.0 | 8.1 | 12 | 11 | 9.8 |
| Chilton [a] | 51°30′N | 01° W | 6.5 | 7.3 | 12 | 9.2 | 8.8 |
| Milford Haven [a] | 51°30′N | 05° W | 7.6 | 7.1 | 11 | 11 | 9.2 |
| Moosonee | 51°16′N | 80°39′W | 6.3 | 6.4 | 12 | 10 | 8.7 |
| Seattle | 47°36′N | 122°20′W | 5.4 | 5.7 | 9.9 | 4.3 | 6.3 |
| Appleton | 44°15′N | 88°25′W | 9.0 | 6.7 | 17 | 14 | 12 |
| Westwood | 41°00′N | 74°01′W | 12 | 6.9 | 17 | 13 | 12 |
| New York | 40°48′N | 73°58′W | 14 | 7.2 | 15 | 13 | 12 |
| Sterling | 38°58′N | 77°25′W | 10 | 6.5 | 15 | 12 | 11 |
| Palo Alto | 37°30′N | 122°23′W | 9.7 | 10 | 16 | 5.6 | 10 |
| Midwest City | 35°25′N | 97°30′W | 12 | 12 | 15 | 9.0 | 12 |
| Chattanooga | 35°03′N | 85°20′W | 12 | 8.4 | 19 | 13 | 13 |
| Miami | 25°49′N | 80°17′W | 8.4 | 12 | 16 | 5.6 | 10 |
| Hong Kong [a] | 22°30′N | 144° E | 7.1 | 7.1 | 8.7 | 2.0 | 6.2 |
| Mauna Loa | 19°28′N | 155°36′W | 3.3 | 8.5 | 11 | 5.0 | 7.0 |
| San Juan | 18°26′N | 66°00′W | 2.7 | 5.0 | 12 | 6.5 | 6.6 |
| Miraflores | 9°00′N | 79°35′W | 0.92 | 4.0 | 7.8 | 1.0 | 3.4 |
| Guayaquil | 2°10′N | 79°52′W | 0.61 | 0.68 | 1.2 | 0.47 | 0.74 |
| Lima | 12°06′S | 77°01′W | 1.3 | 1.4 | 0.77 | 1.1 | 1.1 |
| Chacaltaya | 16°21′S | 68°07′W | 0.84 | 0.29 | 0.37 | 1.1 | 0.65 |
| Antofagasta | 23°37′S | 70°16′W | 1.3 | 0.93 | 0.80 | 1.9 | 1.2 |
| Santiago | 33°27′S | 70°42′W | 1.4 | 1.2 | 0.81 | 1.2 | 1.2 |
| Puerto Montt | 41°27′S | 72°57′W | 0.46 | 0.87 | 0.59 | 0.51 | 0.61 |
| Punta Arenas | 53°08′S | 70°53′W | 0.32 | 0.35 | 0.36 | 0.44 | 0.37 |

[a] United Kingdom ground level air stations

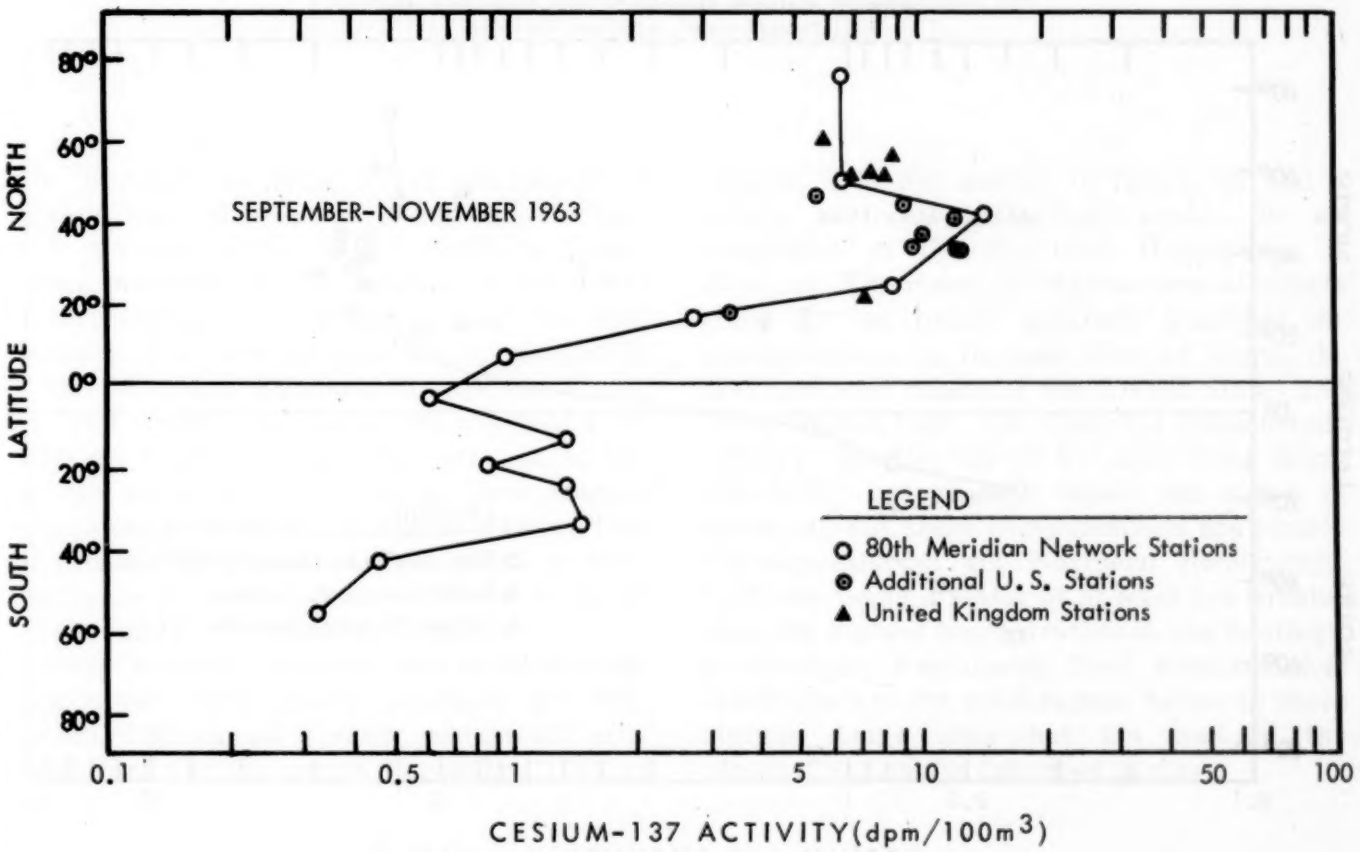


**Figure 6. Profile of cesium–137 air activity, 80th Meridian and selected stations, September–November 1963.**

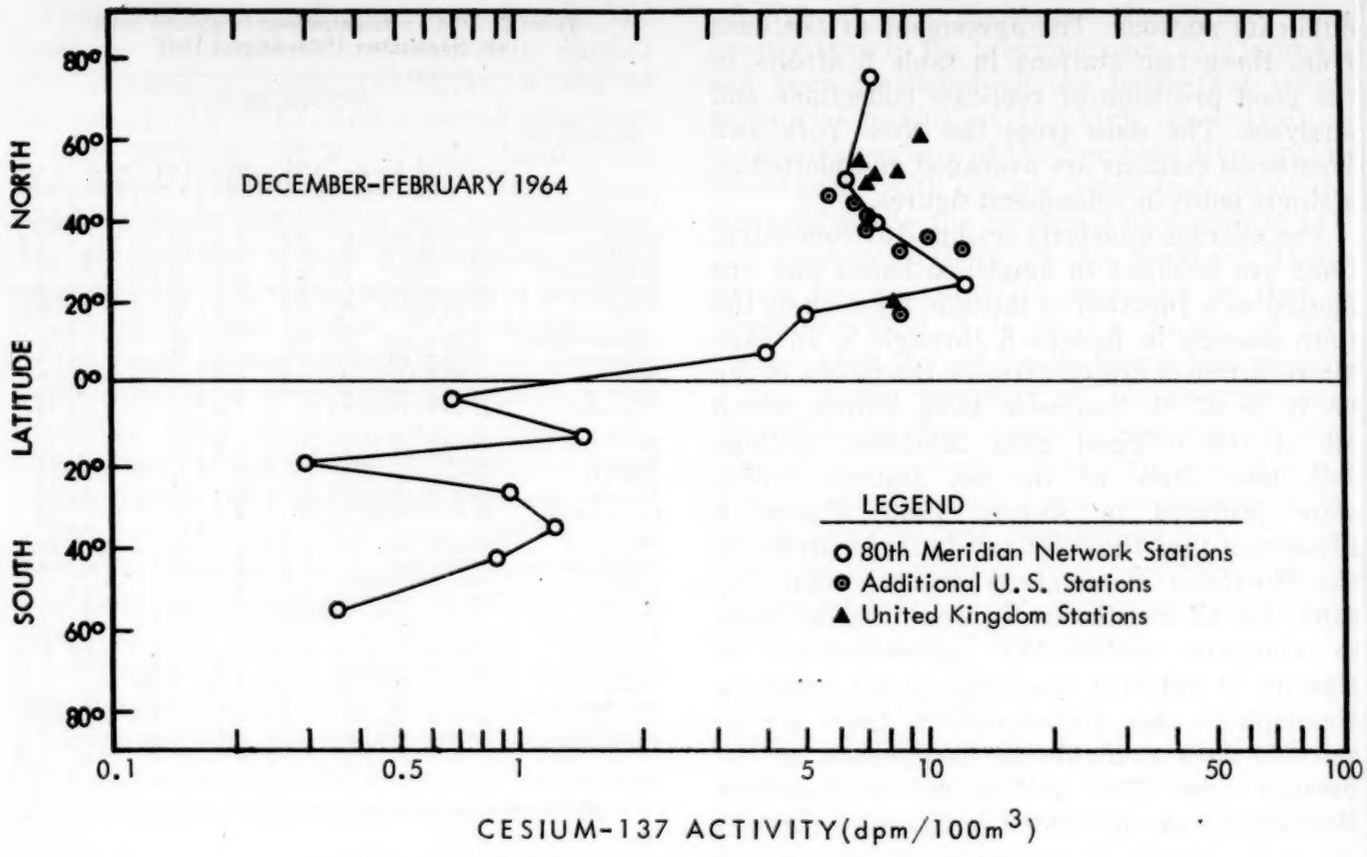


**Figure 7. Profile of cesium–137 air activity, 80th Meridian and selected stations, December 1963–February 1964**

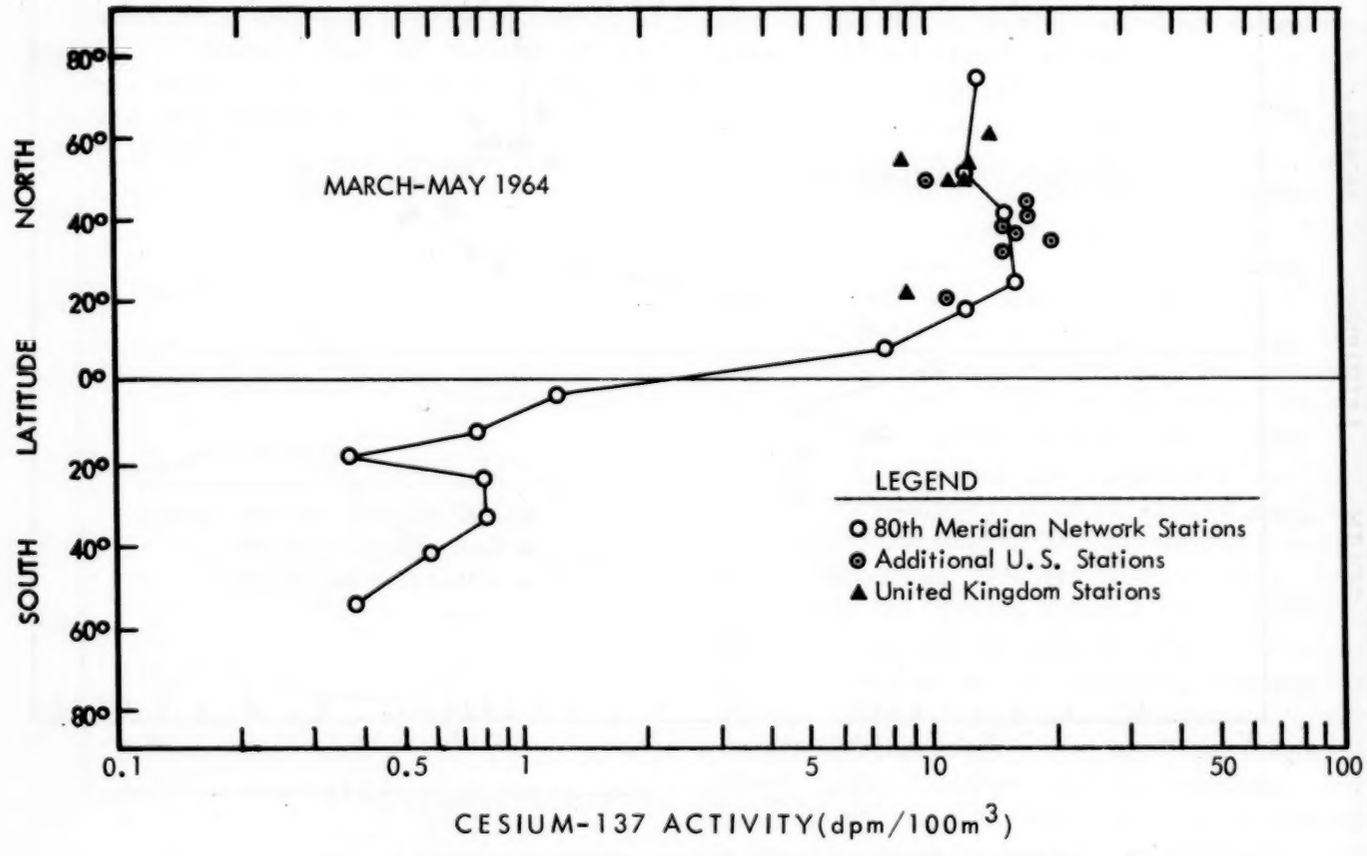


**Figure 8. Profile of cesium–137 air activity, 80th Meridian and selected stations, March–May 1964**

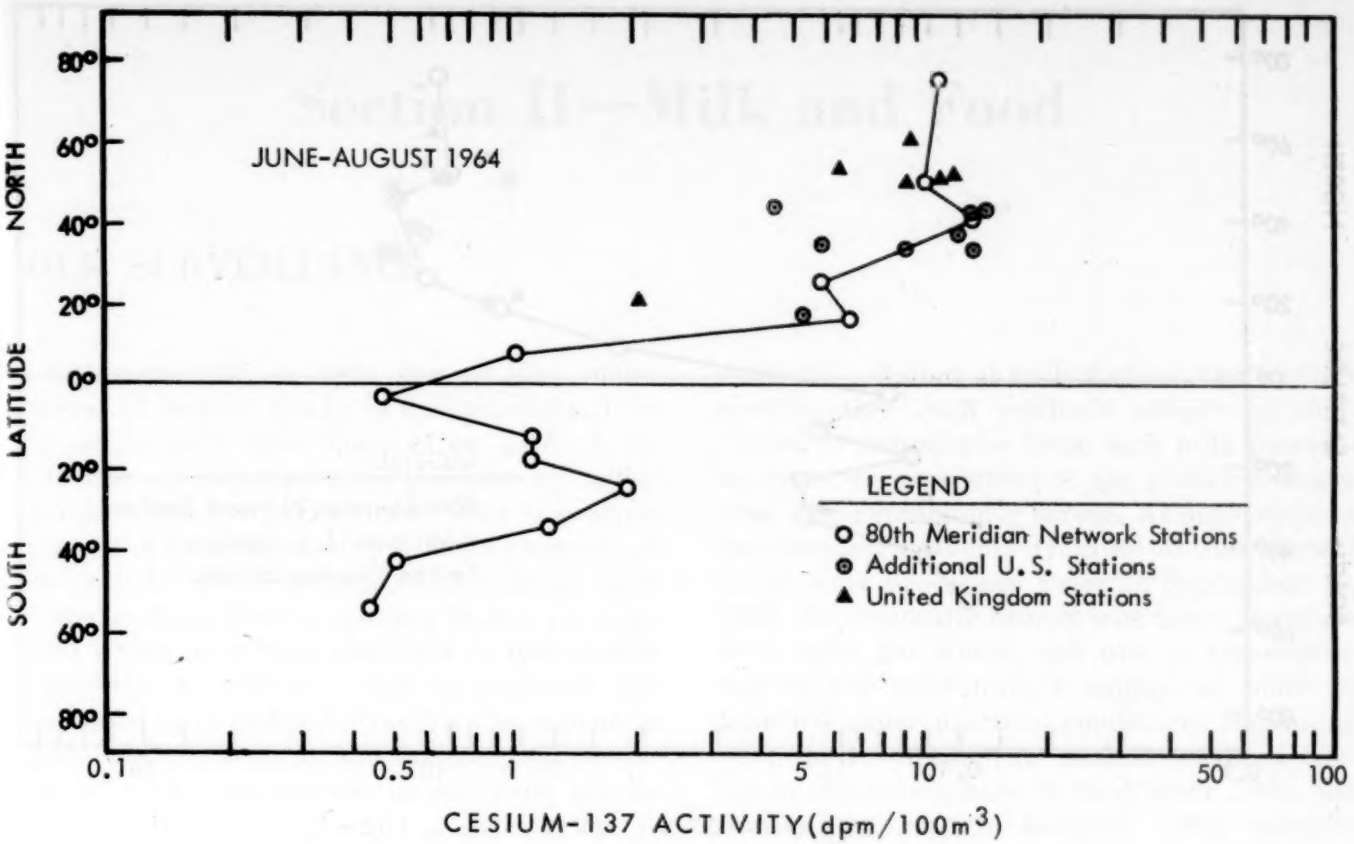


**Figure 9. Profile of cesium–137 air activity, 80th Meridian and selected stations, June–August 1964**

9 to illustrate the disparity of concentrations between hemispheres, and to indicate the lack of a common profile in the Southern Hemisphere although such a common profile exists in the Northern Hemisphere along the 80th Meridian. The same pattern of a single profile in the Northern Hemisphere persists during the 1964 winter and spring (figures 7 and 8), although there is a greater variation of individual points from the line in these seasons than in the preceding fall. Figure 9 shows that the greatest divergence of the stations at other longitudes from the profile of 65°W to 89°W band occurs in the summer of 1964.

These seasonal variations tend to compensate each other when yearly averages are considered. The annual average cesium–137 concentrations for the period September 1963 to August 1964 are plotted in figure 10, and a return to a single latitude profile for all longitudes in the Northern Hemisphere is obtained. There are no serious coastal effects since the one profile generally describes the concentrations on the east coast of China, the east and west coasts of the United States and in the British Isles. The values for Eskdalemuir (55°N), Seattle (47°36′N) and Hong Kong (22°30′N) are slightly below the curve in figure 10, but these concentrations are clearly representative of the Northern Hemispheric latitudes, being a factor of at least five greater than the highest concentration in the Southern Hemisphere. Presumably local meteorological conditions are the predominate factor in these stations being somewhat low and in the seasonal variations described earlier.

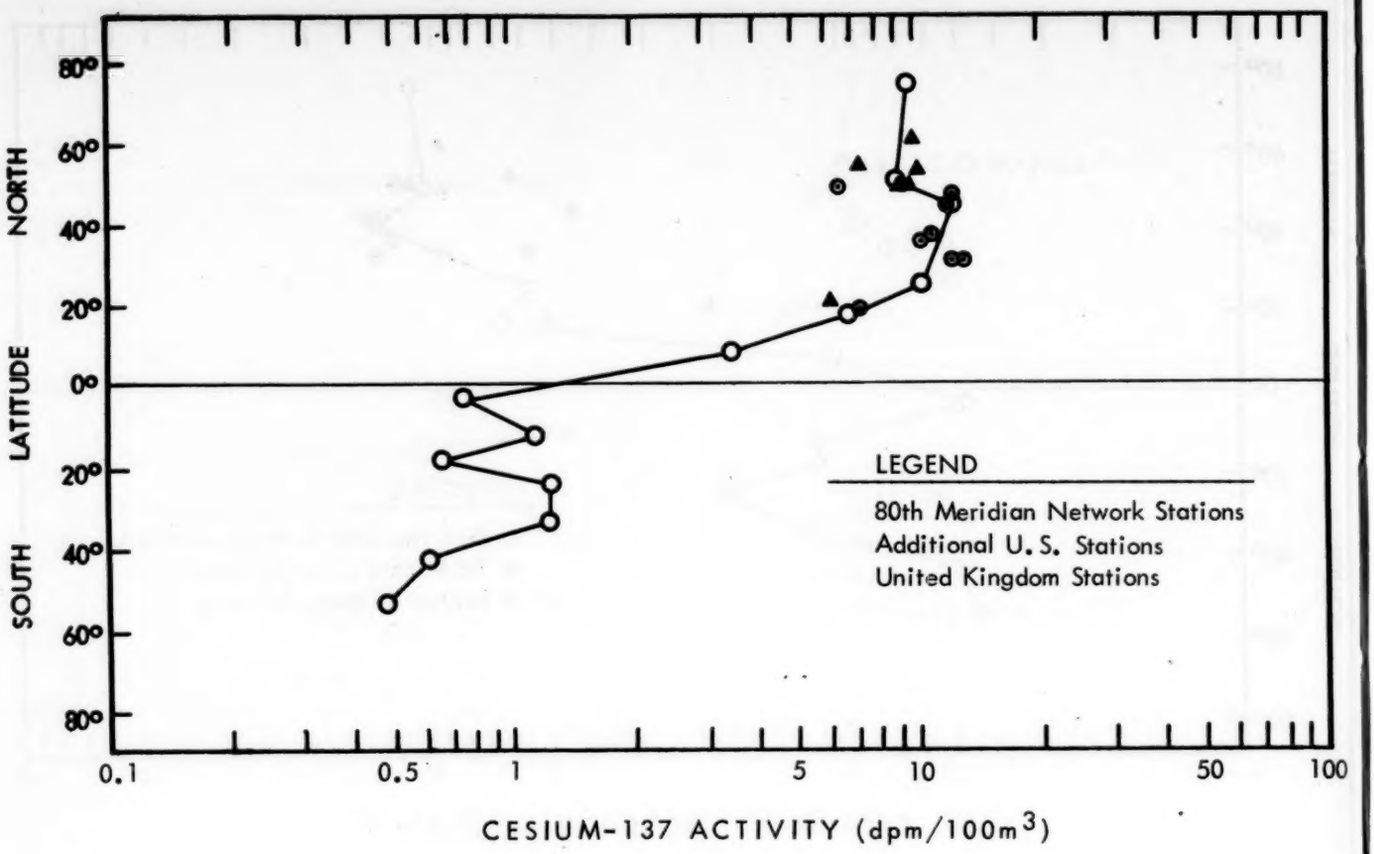


**Figure 10. Profile of annual average cesium–137 air activity, 80th Meridian stations, September 1963–August 1964**

REFERENCES

(*1*) COLLINS, W. R., JR. Fission product gamma activity in surface air—80th Meridian and U.S. locations. Rad Health Data 5:360–362 (August 1964).

(*2*) HEALTH AND SAFETY LABORATORY. HASL surface air sampling network, gamma activity measurements for October 1964. U.S. Atomic Energy Commission, New York, New York 10014 (February 3, 1964).

(*3*) LOCKHART, L. B., JR., R. L. PATTERSON, JR., A. W. SAUNDERS, JR., and R. W. BLACK. Summary Report on Fission Product Radioactivity in the Air Along the 80th Meridian (West) 1957–1962, NRL Report 6104 (June 15, 1964).

(*4*) HEALTH AND SAFETY LABORATORY. HASL surface air sampling program, gamma activity measurements for November 1964. U.S. Atomic Energy Commission, New York, New York 10014 (March 8, 1965).

(*5*) CAMBRAY, R. S., E. M. R. FISHER, G. S. SPICER, C. G. WALLACE, and T. J. WEBBER. Radioactive Fallout in Air and Rain: Results to the Middle of 1964, United Kingdom Atomic Energy Authority Research Group, Report AERE–R–4687 (1964).

# Section II—Milk and Food

## MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to composite and analyze, and samples representative of milk consumption in any area can be readily obtained.

### 1. Pasteurized Milk Network March 1965

*Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service*

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this study led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

*Sampling procedure*

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pCi/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

*Analytical procedures*

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two con-

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

secutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses.

The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, 10; barium–140, 10; and iodine–131, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

**Table 1. Analytical errors associated with estimated concentrations for selected radionuclides in milk**

| Nuclide | Estimated concentration (pCi/liter) | Error [a] (pCi/liter) | Estimated concentration (pCi/liter) | Error [a] (percent of concentration) |
|---|---|---|---|---|
| Iodine-131 | 0 to 100 | ±10 | 100 or greater | ±10 |
| Barium-140 | 0 to 100 | ±10 | 100 or greater | ±10 |
| Cesium-137 | 0 to 100 | ±10 | 100 or greater | ±10 |
| Strontium-89 | 0 to 50 | ± 5 | 50 or greater | ±10 |
| Strontium-90 | 0 to 20 | ± 2 | 20 or greater | ±10 |

[a] Two standard deviations ($2\sigma$).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method, while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

[2] The conversion factor is 1.18 x 10—3 g K/pCi $^{40}$K.

*Data presentation*

Table 2 presents summaries of the analyses for the first quarter of 1965 and the month of March 1965 (actual reporting period is February 28—March 27). The radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similiar procedure is used for the network average.

The quantitative distribution of the number of sampling locations, by ranges of strontium–90 and cesium–137 concentrations in milk for the last 6 months are compared in tables 3 and 4. These tables also provide comparable data for March 1964.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three times a year.

For special purposes of comparison and reference, the network maximum, minimum, and average monthly radionuclide concentrations for the early years of operation (March 1960—March 1964) were summarized in tabular form in the July 1964 *RHD* (*2*). An annual summary for 1964 appeared in the April 1965 RHD (*3*).

*Discussion of Data*

Neither iodine–131 nor barium–140 was detected in the PMN samples during March 1965. Iodine–131 has not been detected in PMN milk samples since November 30, 1964. During

**Table 2. Average concentrations of stable elements and radionuclides in pasteurized milk, March 1965 and the first quarter 1965 [a]**

| Sampling locations | | Calcium (g/liter) | | Strontium-89 (pCi/liter) | | Strontium-90 (pCi/liter) | | Cesium-137 (pCi/liter) | |
|---|---|---|---|---|---|---|---|---|---|
| | | First quarter | Avg. for month | First quarter | Avg. for month | First quarter | Avg. for month | First quarter | Avg. for month |
| Ala: | Montgomery | 1.19 | 1.18 | <5 | <5 | 19 | 18 | 55 | 60 |
| Alaska: | Palmer | 1.18 | 1.19 | <5 | <5 | 17 | 18 | 60 | 60 |
| Ariz: | Phoenix | 1.20 | 1.21 | <5 | <5 | 6 | 5 | 25 | 25 |
| Ark: | Little Rock | 1.18 | 1.18 | <5 | <5 | 34 | 37 | 70 | 75 |
| Calif: | Sacramento | 1.26 | 1.27 | <5 | <5 | 7 | 8 | 35 | 30 |
| | San Francisco | 1.27 | 1.28 | <5 | <5 | 8 | 12 | 35 | 40 |
| C. Z: | Cristobal | 1.14 | 1.12 | <5 | <5 | 5 | 4 | 40 | 35 |
| Colo: | Denver | 1.27 | 1.28 | <5 | <5 | 18 | 18 | 70 | 90 |
| Conn: | Hartford | 1.12 | 1.12 | <5 | <5 | 16 | 16 | 90 | 95 |
| Del: | Wilmington | 1.15 | 1.14 | <5 | <5 | 19 | 20 | 80 | 80 |
| D. C: | Washington | 1.17 | 1.19 | <5 | <5 | 17 | 16 | 60 | 65 |
| Fla | Tampa | 1.18 | 1.17 | <5 | <5 | 13 | 13 | 160 | 165 |
| Ga: | Atlanta | 1.19 | 1.16 | <5 | <5 | 26 | 28 | 90 | 95 |
| Hawaii: | Honolulu | 1.18 | 1.18 | <5 | <5 | 11 | 10 | 65 | 60 |
| Idaho: | Idaho Falls | 1.21 | 1.26 | <5 | <5 | 21 | 21 | 110 | 110 |
| Ill: | Chicago | 1.12 | 1.12 | <5 | <5 | 17 | 18 | 90 | 95 |
| Ind: | Indianapolis | 1.19 | 1.18 | <5 | <5 | 17 | 18 | 75 | 75 |
| Iowa: | Des Moines | 1.20 | 1.25 | <5 | <5 | 22 | 24 | 60 | 60 |
| Kans: | Wichita | 1.24 | 1.25 | <5 | <5 | 18 | 18 | 55 | 55 |
| Ky: | Louisville | 1.17 | 1.16 | <5 | <5 | 22 | 22 | 60 | 60 |
| La: | New Orleans | 1.23 | 1.22 | 5 | 10 | 43 | 44 | 80 | 100 |
| Maine: | Portland | 1.14 | 1.14 | <5 | <5 | 22 | 22 | 135 | 125 |
| Md: | Baltimore | 1.16 | 1.13 | <5 | <5 | 18 | 18 | 65 | 70 |
| Mass: | Boston | 1.16 | 1.16 | <5 | <5 | 23 | 24 | 140 | 145 |
| Mich: | Detroit | 1.15 | 1.14 | <5 | <5 | 16 | 16 | 85 | 90 |
| | Grand Rapids | 1.18 | 1.19 | <5 | <5 | 19 | 20 | 90 | 100 |
| Minn: | Minneapolis | 1.22 | 1.27 | <5 | <5 | 26 | 28 | 90 | 95 |
| Miss: | Jackson | 1.25 | 1.24 | <5 | <5 | 34 | 36 | 60 | 70 |
| Mo: | Kansas City | 1.22 | 1.24 | <5 | <5 | 22 | 26 | 60 | 60 |
| | St. Louis | 1.25 | 1.28 | <5 | <5 | 17 | 16 | 50 | 55 |
| Mont: | Helena | 1.25 | 1.29 | <5 | <5 | 18 | 18 | 95 | 100 |
| Nebr: | Omaha | 1.25 | 1.26 | <5 | <5 | 18 | 19 | 50 | 55 |
| Nev: | Las Vegas | 1.20 | 1.23 | <5 | <5 | 9 | 8 | 40 | 40 |
| N. H: | Manchester | 1.16 | 1.16 | <5 | <5 | 24 | 23 | 155 | 150 |
| N. J: | Trenton | 1.13 | 1.15 | <5 | <5 | 16 | 16 | 80 | 80 |
| N. Mex: | Albuquerque | 1.22 | 1.23 | <5 | <5 | 12 | 10 | 45 | 50 |
| N. Y: | Buffalo | 1.11 | 1.10 | <5 | <5 | 17 | 17 | 110 | 110 |
| | New York | 1.12 | 1.14 | <5 | <5 | 19 | 21 | 105 | 100 |
| | Syracuse | 1.11 | 1.15 | <5 | <5 | 16 | 16 | 95 | 95 |
| N. C: | Charlotte | 1.20 | 1.16 | <5 | <5 | 29 | 29 | 65 | 65 |
| N. Dak: | Minot | 1.21 | 1.24 | <5 | <5 | 52 | 53 | 125 | 120 |
| Ohio: | Cincinnati | 1.16 | 1.16 | <5 | <5 | 17 | 17 | 70 | 70 |
| | Cleveland | 1.16 | 1.17 | <5 | <5 | 18 | 18 | 95 | 100 |
| Okla: | Oklahoma City | 1.18 | 1.14 | <5 | <5 | 21 | 26 | 55 | 55 |
| Ore: | Portland | 1.28 | 1.28 | <5 | <5 | 20 | 23 | 100 | 100 |
| Pa: | Philadelphia | 1.16 | 1.16 | <5 | <5 | 17 | 17 | 80 | 80 |
| | Pittsburgh | 1.16 | 1.15 | <5 | <5 | 24 | 24 | 105 | 110 |
| P. R: | San Juan | 1.14 | 1.12 | <5 | <5 | 12 | 11 | 50 | 45 |
| R. I: | Providence | 1.16 | 1.15 | <5 | <5 | 19 | 18 | 100 | 95 |
| S. C: | Charleston | 1.20 | 1.20 | <5 | <5 | 30 | 32 | 85 | 90 |
| S. Dak: | Rapid City | 1.03 | 1.08 | <5 | <5 | 28 | 31 | 135 | 130 |
| Tenn: | Chattanooga | 1.22 | 1.21 | <5 | <5 | 31 | 30 | 70 | 70 |
| | Memphis | 1.20 | 1.18 | <5 | <5 | 26 | 26 | 45 | 45 |
| Tex: | Austin | 1.15 | 1.15 | <5 | <5 | 9 | 9 | 35 | 35 |
| | Dallas | 1.19 | 1.21 | <5 | <5 | 18 | 19 | 45 | 45 |
| Utah: | Salt Lake City | 1.30 | 1.35 | <5 | <5 | 25 | 22 | 125 | 125 |
| Vt: | Burlington | 1.12 | 1.14 | <5 | <5 | 21 | 23 | 120 | 125 |
| Va: | Norfolk | 1.19 | 1.18 | <5 | <5 | 21 | 22 | 60 | 60 |
| Wash: | Seattle | 1.26 | 1.26 | <5 | <5 | 23 | 20 | 90 | 90 |
| | Spokane | 1.28 | 1.30 | <5 | <5 | 26 | 32 | 100 | 95 |
| W. Va: | Charleston | 1.18 | 1.18 | <5 | <5 | 16 | 17 | 50 | 50 |
| Wis: | Milwaukee | 1.20 | 1.21 | <5 | <5 | 14 | 15 | 100 | 105 |
| Wyo: | Laramie | 1.25 | 1.22 | <5 | <5 | 13 | 11 | 65 | 60 |
| Network average | | 1.19 | 1.19 | <5 | <5 | 19.9 | 20.4 | 79 | 81 |

[a] Results of barium-140 and iodine-131 analyses all zero.

**Table 3. Ranges of station monthly averages for strontium-90, October–December 1964, January–March 1965 and March 1964**

| Range, pCi/liter | Number of stations in range | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1964 | | | 1965 | | | 1964 |
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | March |
| Under 10 | 6 | 6 | 8 | 6 | 3 | 5 | 2 |
| 10–19 | 37 | 31 | 29 | 32 | 31 | 29 | 17 |
| 20–29 | 13 | 19 | 20 | 19 | 22 | 21 | 30 |
| 30–39 | 7 | 6 | 4 | 4 | 5 | 6 | 10 |
| 40–49 | 0 | 1 | 2 | 1 | 2 | 1 | 2 |
| 50–59 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 60–69 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 4. Ranges of station monthly averages for cesium-137, October–December 1964, January–March 1965 and March 1964**

| Range, pCi/liter | Number of stations in range | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1964 | | | 1965 | | | 1964 |
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | March |
| Under 50 | 16 | 15 | 9 | 11 | 8 | 9 | 2 |
| 50–99 | 40 | 41 | 38 | 38 | 38 | 36 | 11 |
| 100–149 | 6 | 4 | 14 | 12 | 15 | 16 | 22 |
| 150–199 | 0 | 2 | 2 | 2 | 2 | 2 | 20 |
| 200–249 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| 250–299 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

the period of October 26, 1964, through November 30, 1964, iodine–131 was detected in 45 samples and was attributed to the detonation of a nuclear device by the Communist Chinese on October 16, 1964.

Slight increases in the March strontium–90 monthly averages were observed for 26 stations while levels at 20 stations decreased slightly from the previous month. The network average of 63 stations for March 1965 was 20.4 pCi/liter compared to 20.2 pCi/liter in February. The network average for March 1965 was 20 percent lower than March 1964. The ratio of the highest concentration to the average concentration was 2.60 for March 1965 compared to 2.64 for March 1964.

Slight increases in the March cesium–137 monthly averages were observed for 27 stations while levels at 21 stations decreased slightly from the previous month. The network average of 63 stations for March 1965 was 81 pCi/liter compared to 80 pCi/liter in February. The network average was 40 percent lower for March 1965 than March 1964. The ratio of the highest concentration to the average concentration was 2.04 for March 1965 compared to 1.91 for March 1964.

Since the March network averages for both strontium–90 and cesium–137 are lower this year than last and the ratios of maximum concentration to average concentration remained essentially constant, a continued decrease in radionuclide concentrations in milk should be observed provided fresh fission debris is not introduced into the atmosphere.

Neither strontium–90 nor cesium–137 have exhibited a "spring rise" during February and March 1965. To further support this, the number of stations reporting increased levels over the previous month was approximately equal to the number of stations reporting decreased levels over the previous month for both radionuclides.

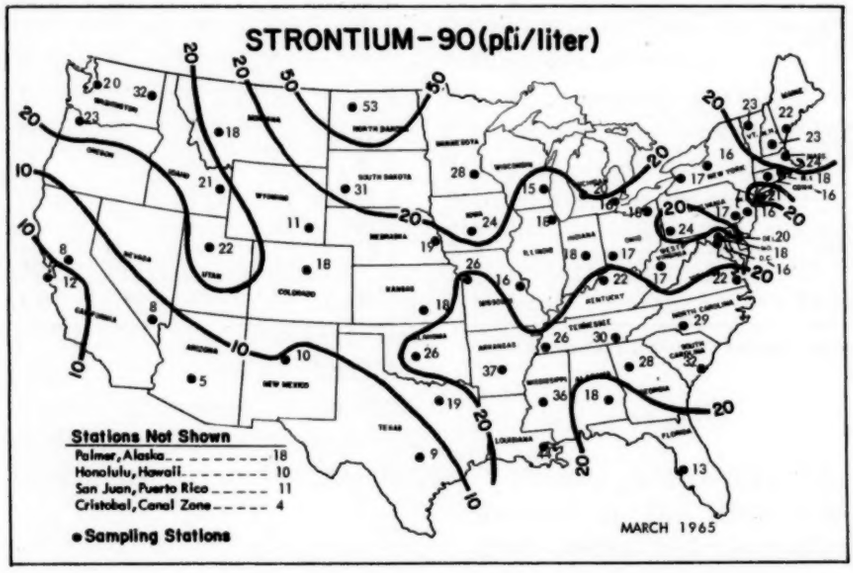


**Figure 1. Strontium–90 concentrations in pasteurized milk, March 1965**

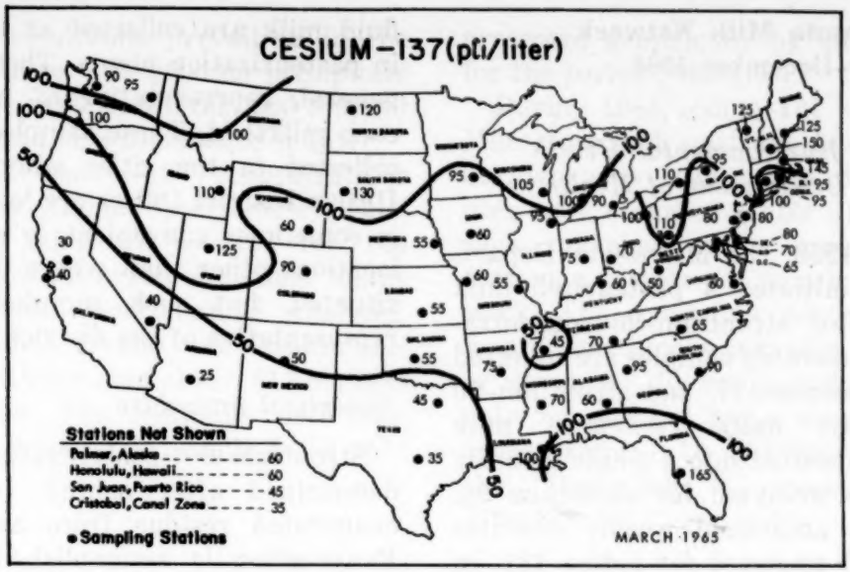


**Figure 2. Cesium–137 concentrations in pasteurized milk, March 1965**

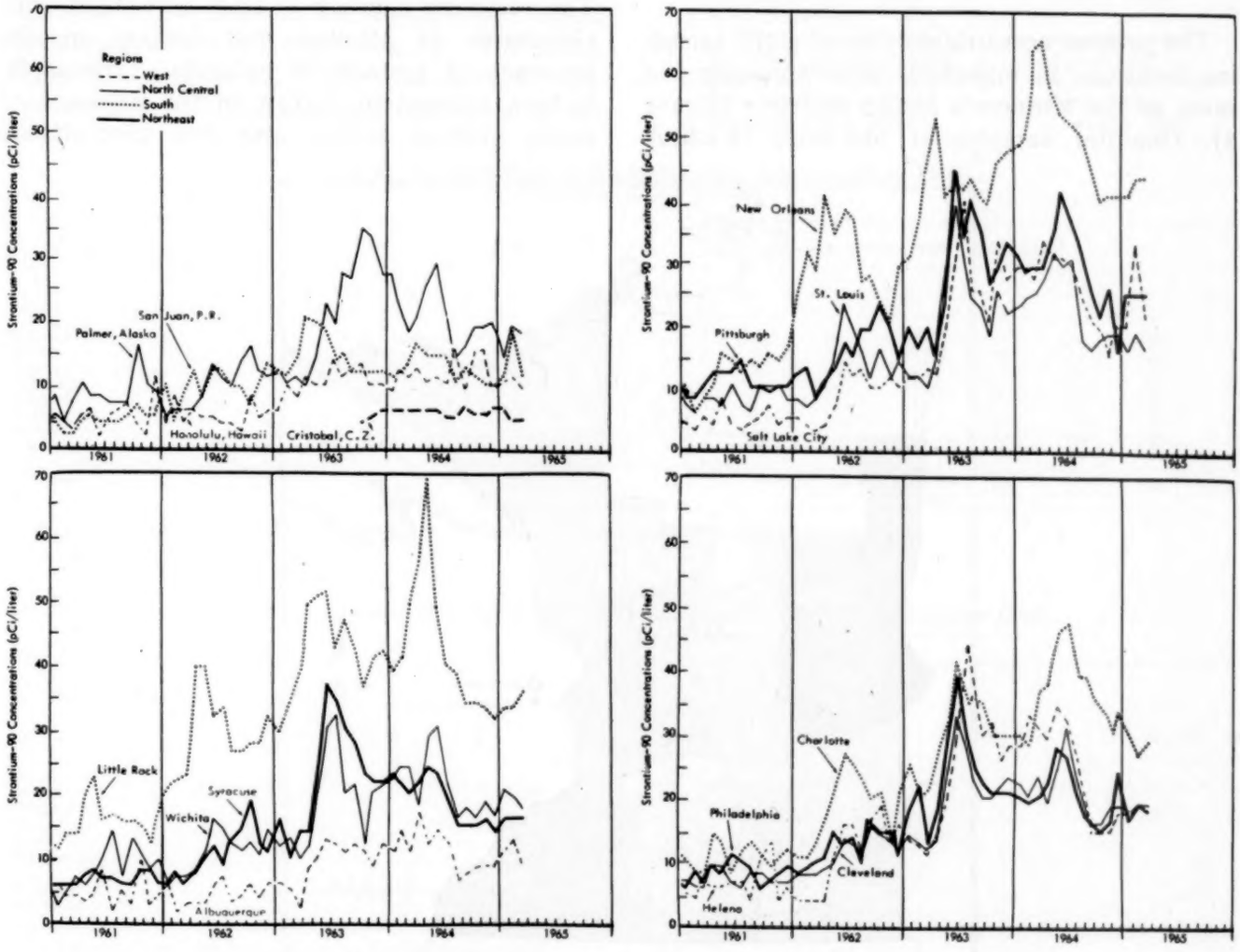


**Figure 3. Strontium–90 concentrations in pasteurized milk, 1961–March 1965**

## 2. Minnesota Milk Network July–December 1964

*Division of Environmental Health*
*Minnesota Department of Health*

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium–90 concentrations. At present, monthly samples are collected for iodine–131, cesium–137, and strontium–90 analyses. Initially, daily two-ounce milk samples were composited into a single monthly sample which was analyzed for strontium–90. In October 1961, additional weekly one-liter grab samples were analyzed for iodine–131. In November 1962, strontium–90 analyses were reduced to a single monthly sample composited of weekly samples. This procedure was continued until August 1963 when the current procedure was initiated.

The present network consists of eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 4). One-liter samples of processed Grade-A fluid milk are collected at bottling machines in pasteurization plants. These samples are, in general, representative of milk marketed in each milkshed. These samples are customarily collected in the cities where the Minnesota Health District Offices are located. However, it is sometimes convenient to collect samples at locations other than where district offices are situated, but such samples are considered representative of the district concerned.

### *Analytical procedure*

Strontium–90 concentrations in milk are determined after ashing (at 450° C) the evaporated residue from an 800-ml sample. Evaporation is accomplished by means of a steam bath and infrared overhead heating. Oxalates of calcium and strontium are precipitated at a pH of 4 from a nitric acid solution of the ash. The separated oxalates are then decomposed with nitric acid and peroxide. The resulting solution is then scavenged with chromates of yttrium and barium in the presence of ammonium chloride. Yttrium–90 is then allowed to ingrow in the presence of stable yttrium carrier and then precipitated

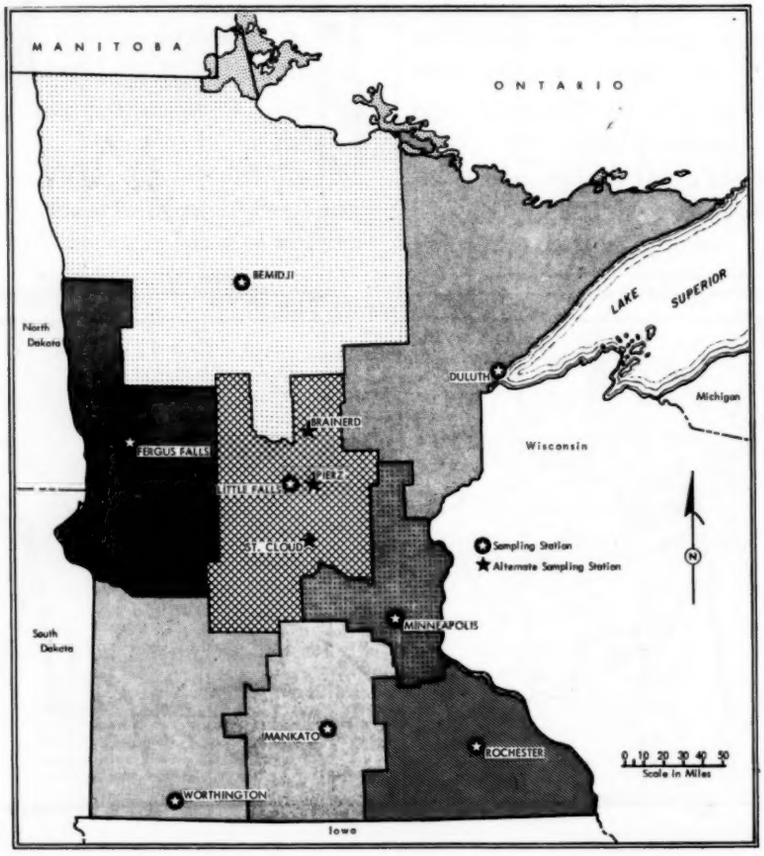


**Figure 4. Minnesota milk sampling locations**

under the same conditions prevailing in the scavenging procedure. The yttrium precipitate is converted to the oxalate, filtered, and counted in a low-background anticoincidence counter.

Iodine–131 and cesium–137 concentrations are determined by gamma spectrometry. One-liter samples of milk are counted for 100 minutes with a low-background sodium iodine crystal detector and multichannel analyzer. Either a 3 x 3-inch crystal and 256-channel analyzer or a 4 x 4-inch crystal and 512-channel analyzer are used. The minimum detectable concentration of iodine–131 in milk is 10 pCi/liter.

*Results*

The monthly strontium–90, iodine–131, and cesium–137 concentrations in milk are given in table 5 for July through December 1964. These data as well as analytical procedures are presented in the semiannual report of the Minnesota Department of Health and Rural Cooperative Power Association (*4*). The strontium–90, cesium–137, and iodine–131 concentrations in Minnesota pasteurized milk are presented graphically by milkshed in figure 5 for the period 1962-1964.

During 1964, iodine–131 was not detected in Minnesota milk until the first week in November, when levels in excess of 10 picocuries per liter were observed (table 6). Collections from each milkshed were immediately increased from one sample per month to one sample per week. The maximum concentration observed was 53 picocuries per liter in the early part of November. By the second week in December, only one of eight had a measurable iodine–131 concentration—18 pCi/liter was observed in the December 5 weekly sample from Worthington.

Previous coverage in *Radiological Health Data:*

| Period | Issue |
|---|---|
| October–December 1961 (Iodine–131 data) | *March 1962* |
| May–December 1961 (Strontium–90 data) | *August 1962* |
| March–September 1962 | *April 1963* |
| September 1962–June 1963 | *November 1963* |
| July–December 1963 | *June 1964* |
| January–June 1964 | *January 1965* |

**Table 5. Radionuclides in Minnesota milk, July–December 1964** [a]

(Concentrations in pCi/liter)

| Sampling location (District office) | Strontium-90 | | | | | | Cesium-137 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | July | Aug | Sept | Oct | Nov | Dec | July | Aug | Sept | Oct | Nov | Dec |
| Bemidji | 54 | 35 | 43 | 33 | 41 | 38 | 330 | 220 | 185 | 170 | 170 | 190 |
| Duluth | 62 | 35 | 40 | 39 | 39 | 33 | 430 | 250 | 270 | 170 | 160 | 200 |
| Fergus Falls | 27 | 25 | 19 | 20 | 19 | 20 | 100 | 140 | 120 | 110 | 95 | 100 |
| Little Falls | [b] 42 | [c] 31 | [c] 25 | 16 | [c] 27 | 17 | [b] 380 | [c] 250 | [c] 200 | 99 | [c] 85 | 220 |
| Mankato | 20 | 17 | 17 | 22 | 15 | 12 | 230 | 110 | 100 | 60 | 55 | 85 |
| Minneapolis | 24 | 25 | 27 | 13 | 21 | 15 | 180 | 140 | 130 | 64 | 92 | 131 |
| Rochester | 22 | 17 | 18 | 19 | 18 | 13 | 150 | 92 | 85 | 63 | 64 | 90 |
| Worthington | 25 | 16 | 14 | 14 | 14 | 13 | 170 | 70 | 76 | 69 | 50 | 70 |
| Averages | 35 | 25 | 25 | 22 | 24 | 20 | 250 | 160 | 120 | 100 | 100 | 140 |

[a] Each monthly iodine-131 concentration at each station was below the minimum detectable concentration.
[b] Sample collected at Pierz.
[c] Sample collected at Brainerd.

**Table 6. Appearance of iodine-131 in Minnesota milk, November–December 1964**

(Concentrations in pCi/liter)

| Sampling location (District office) | November [a] | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Bemidji | ---- | 34 | ---- | ---- | ---- | ---- | ---- | ---- | 37 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | |
| Duluth | ---- | 53 | ---- | ---- | ---- | ---- | 19 | ---- | ---- | ---- | ---- | ---- | 24 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 17 | ---- | ---- | |
| Fergus Falls | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | 20 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 14 |
| Little Falls | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | 14 | |
| Mankato | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | 12 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | <10 | ---- | ---- | |
| Minneapolis | ---- | 19 | <10 | ---- | ---- | ---- | ---- | 19 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 26 | |
| | | | | | | | | [b] 24 | | | | | | | | | | | | | | | [c] 19 | |
| Rochester | ---- | ---- | 22 | ---- | ---- | ---- | ---- | ---- | 15 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | |
| Worthington | ---- | ---- | ---- | <10 | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | ---- | ---- | ---- | ---- | <10 | ---- | ---- | |

[a] After November 24, $^{131}I$ levels were below the detection limit.
[b] Composite Minneapolis—St. Paul sample.
[c] Check sample.

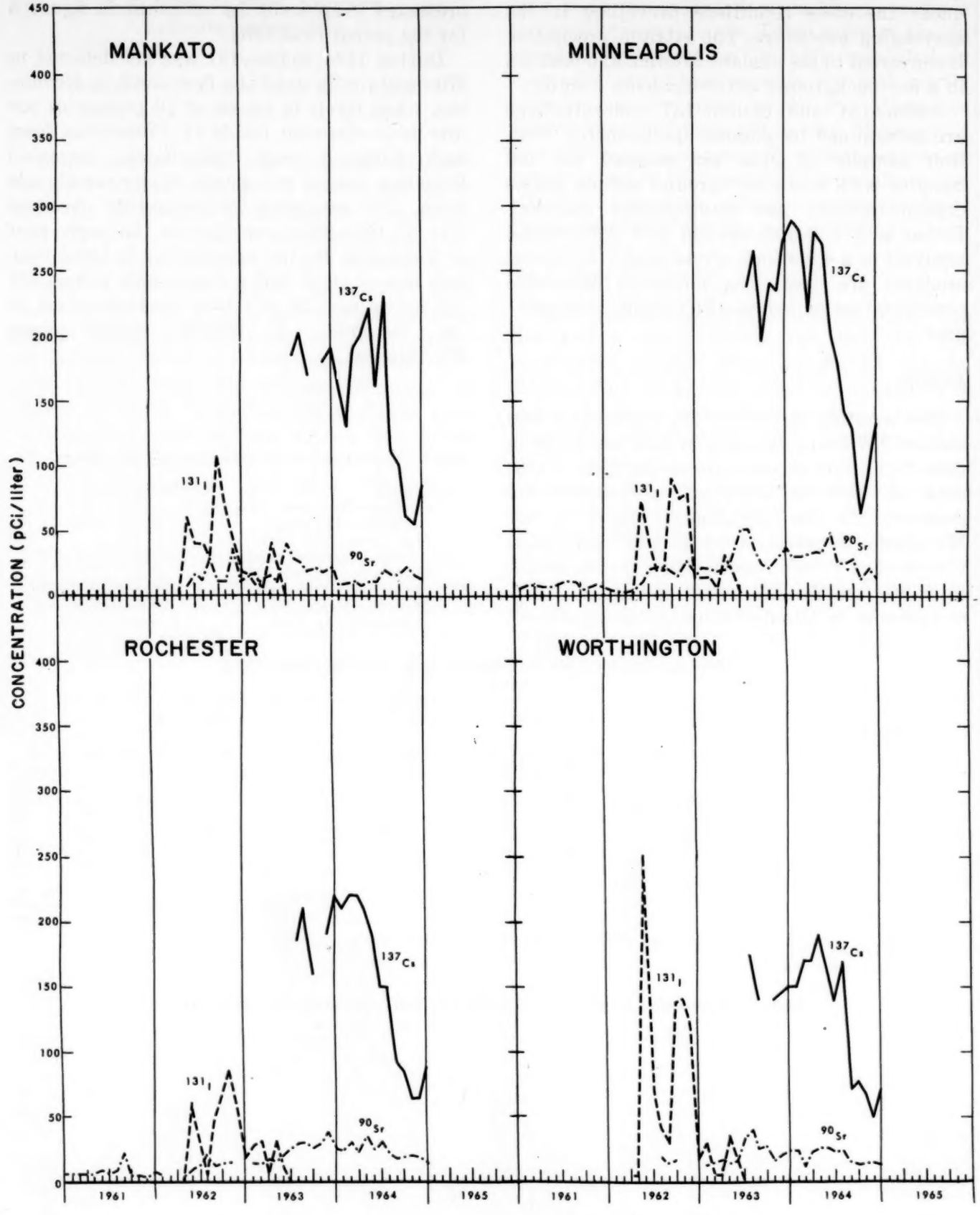


**Figure 5. Radionuclide concentrations in Minnesota milk, 1961 to December 1964 (November 1964 iodine–131 data omitted—see table 6)**

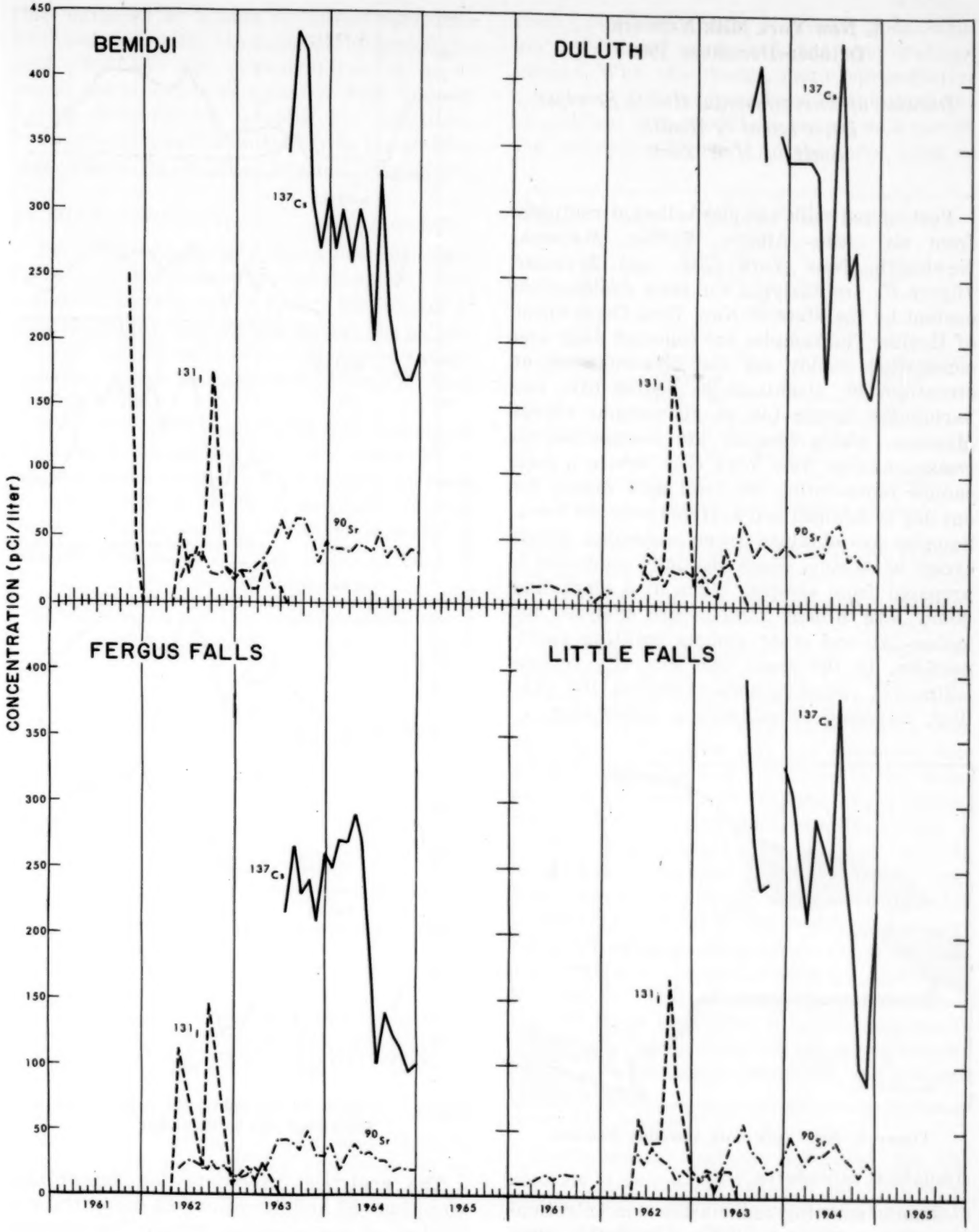


**Figure 5. Radionuclide concentrations in Minnesota milk, 1961 to December 1964 (November 1964 iodine-131 data omitted—see table 6)—continued**

## 3. New York Milk Network October–December 1964

*Division of Environmental Health Services*
*Department of Health,*
*State of New York*

Pasteurized milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 6) are analyzed for their radionuclide content by the State of New York Department of Health. The samples are collected daily and composited weekly for the determination of strontium–89, strontium–90, iodine–131, and barium-lanthanum–140 at all stations except Massena, where samples are composited bi-weekly, and at New York City, where a milk sample representing the total milk supply for one day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily composite is prepared from samples taken at a marketing point. The Albany samples are analyzed for iodine–131 and other gamma emitting radionuclides. In the event that any city reports iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

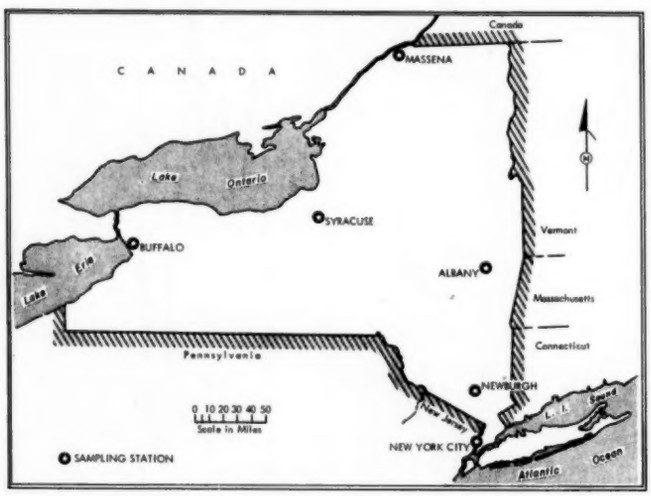


**Figure 6. New York milk sampling locations**

### *Analytical procedures*

Gamma emitting radionuclide concentrations in milk are determined by scintillation spectrometry and the application of a matrix method of analysis to the resultant spectral data. (*5*)

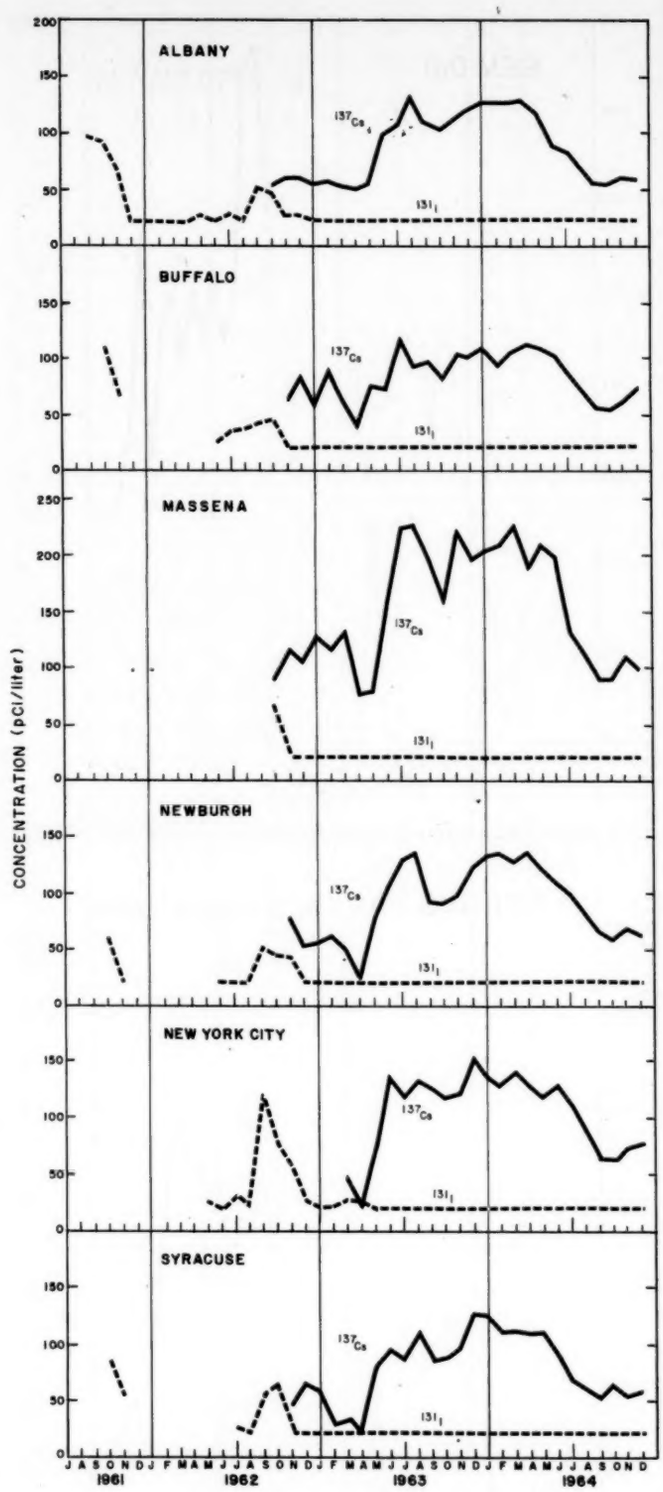


**Figure 7. Cesium–137 and iodine–131 in New York milk, September 1961 to December 1964**

The analytical procedure for determining strontium–89 and strontium–90 concentrations employs an ion exchange system. The collected cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution. The strontium isotopes are

then gathered by means of sodium carbonate and isolated with ethylenediaminetetraacetic acid (EDTA). The radiostrontium is determined with a low-background beta counter having an 0.8 mg/cm$^2$ window. The strontium–90 is determined differentially from the 40-hour ingrowth of its daughter product, yttrium–90.

*Results and discussion*

The monthly average radionuclide concentrations of strontium–89, strontium–90, and cesium–137 are shown in table 7 for October to December 1964. During this period, the iodine–131 and barium-lanthanum–140 concentrations remained below the minimum detectable level of 20 pCi/liter.

The cesium–137 and iodine–131 concentrations since September 1961 are presented in figure 7. These results reflect a general decrease in cesium–137 since the atmospheric nuclear test ban treaty, despite the slight increase in October 1964.

**Table 7. Average radionuclide concentrations (pCi/liter) in New York milk, October–December 1964**

| Sampling location | Strontium-89 | | | Strontium-90 | | | Cesium-137 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Oct | Nov | Dec | Oct | Nov | Dec |
| Albany | <3 | <3 | <3 | 14 | 14 | 14 | 57 | 61 | 60 |
| Buffalo | 3 | <3 | <3 | 11 | 13 | 13 | 50 | 60 | 73 |
| Massena | 5 | 4 | <3 | 17 | 19 | 9 | 88 | 111 | 100 |
| Newburgh | <3 | <3 | 4 | 11 | 18 | 15 | 58 | 63 | 59 |
| New York City | <3 | <3 | <3 | 16 | 21 | 20 | 64 | 74 | 78 |
| Syracuse | <3 | <3 | <3 | 14 | 14 | 14 | 65 | 55 | 60 |
| Average | <3 | <3 | <3 | 14 | 17 | 14 | 64 | 71 | 57 |

## 4. Canadian Milk Network[3] March 1965

*Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada*

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first, analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (figure 8) in the same areas as

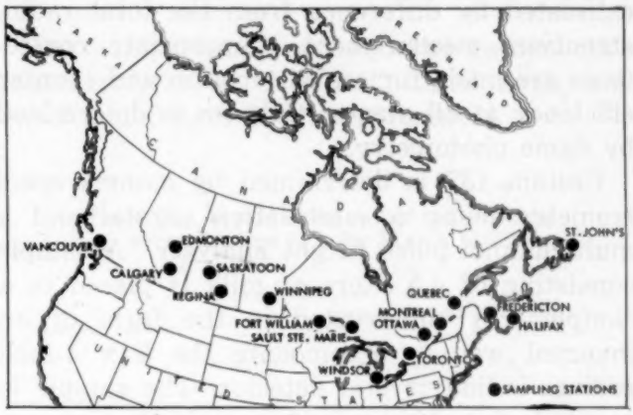


**Figure 8. Canadian milk sampling stations**

the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

*Analytical methods*

Radiochemical methods are used for the analysis of iodine–131 (*6*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C.,

[3] Data from *Radiation Protection Programs*, Vol. 3, No. 4: 25–26. Radiation Protection Division, Canadian Department of National Health and Welfare (April 1965).

dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low-background beta counter. Strontium–90 is determined separately by extracting and counting its yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectrometry using a scintillation crystal and a multichannel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accomodate the 5 x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

*Sources of error*

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radionuclide in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 8.

*Results*

Table 9 presents monthly averages of strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had insignificant levels of these radionuclides.

The results show that radionuclide concentrations in Canadian whole milk remained well below the levels permissible on health grounds.

**Table 8. Total error for various radionuclide concentrations in milk [a]**

| Radionuclide | Error for 10 pCi/liter | Error for 50 pCi/liter | Error for 100 pCi/liter |
|---|---|---|---|
| Strontium-89 | ±25% | ±20% | ±15% |
| Strontium-90 | ±15% | ±10% | ±10% |
| Iodine-131 | ±50% | ±20% | ±10% |
| Cesium-137 | ±60% | ±20% | ±10% |

[a] All errors are $2\sigma$ values, representing 95 percent confidence levels.

**Table 9. Radionuclides in Canadian whole milk, March 1965 [a]**

| Station | Calcium (g/liter) | Potassium (g/liter) | Strontium-90 (pCi/liter) | Cesium-137 (pCi/liter) |
|---|---|---|---|---|
| Calgary | 1.13 | 1.5 | 24.8 | 108 |
| Edmonton | 1.14 | 1.5 | 22.3 | 116 |
| Ft. William | 1.11 | 1.7 | 43.0 | 193 |
| Fredericton | 1.13 | 1.7 | 33.3 | 196 |
| Halifax | 1.13 | 1.7 | 39.0 | 260 |
| Montreal | 1.04 | 1.7 | 26.4 | 164 |
| Ottawa | 1.16 | 1.7 | 21.6 | 126 |
| Quebec | 1.09 | 1.6 | 41.0 | 254 |
| Regina | 1.09 | 1.6 | 25.2 | 129 |
| St. John's, Nfld | 1.10 | 1.5 | 34.9 | 181 |
| Saskatoon | 1.13 | 1.7 | 26.4 | 112 |
| Sault Ste. Marie | 1.06 | 1.6 | 34.1 | 176 |
| Toronto | 1.02 | 1.7 | 13.3 | 88 |
| Vancouver | 1.16 | 1.6 | 36.3 | 251 |
| Windsor | 1.12 | 1.6 | 15.2 | 88 |
| Winnipeg | 1.11 | 1.7 | 27.2 | 151 |
| Average | 1.11 | 1.6 | 29.0 | 162 |

[a] Due to insignificant levels of strontiun-89 the reporting of this nuclide has been discontinued.

## 5. Pan American Milk Sampling Program March 1965

*Pan American Health Organization, and Public Health Service*

In accordance with a joint agreement, the PAHO (Pan American Health Organization) and the PHS (Public Health Service) developed a collaborative program for furnishing assistance to health authorities in the Americas engaged in developing programs in radiological health.

Under this agreement, the PHS Division of Radiological Health furnishes to PAHO, on a loan basis, limited quantities of essential items of equipment and the requisite laboratory services to establish a surveillance program.

### *Sampling procedure*

Initially, air sampling stations were established in Chile, Jamaica, Peru, and Venezuela. In August 1963 this was expanded to include a milk sampling station in Caracas, Venezuela. Between April 1964 and August 1964, milk stations were added in Jamaica at Kingston, Montego Bay, and Mandeville. Sampling varies according to local procedures.

Under the direction of the Venezuelan Institute for Scientific Investigation, weekly samples are collected, preserved with formaldehyde and composited monthly.

Jamaica, under the direction of the Ministry of Health, collects one monthly composite on a rotating basis from one of the three principal milk areas: Montego Bay (Montpelier), Mandeville, and Kingston (Spanish Town). To reduce spoilage it was necessary to establish cooling stations in the western parishes where the milk is received prior to shipping to the Condensery in Kingston. All samples are sent to the PHS Southeastern Radiological Health Laboratory for analyses.

### *Analytical procedures*

Iodine–131 and cesium–137 are determined by gamma scintillation spectrometry. Strontium–89, strontium–90, and barium–140 are determined radiochemically (*7*). Analytical errors are discussed in the 'Analytical Procedures' of article 1, "Pasteurized Milk Network," page 351.

### *Data presentation*

Table 10 presents stable calcium and potassium, strontium–89, strontium–90, and cesium–137 monthly average concentrations. The monthly average of iodine–131 and barium–140 concentrations in milk were less than 10 pCi/liter.

For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico are presented.

**Table 10. Stable element and radionuclide concentrations in milk, March 1965**

| Sampling stations | Calcium (g/liter) | Potassium (g/liter) | Strontium-89 (pCi/liter) | Strontium-90 (pCi/liter) | Cesium-137 (pCi/liter) |
|---|---|---|---|---|---|
| Canal Zone: | | | | | |
| Cristobal | 1.12 | 1.5 | <5 | 4 | 35 |
| Jamaica: | | | | | |
| Kingston | 1.17 | 1.39 | <5 | 18 | 275 |
| Mandeville | * NS | NS | NS | NS | NS |
| Montego Bay | NS | NS | NS | NS | NS |
| Puerto Rico: | | | | | |
| San Juan | 1.12 | 1.6 | <5 | 11 | 45 |
| Venezuela: | | | | | |
| Caracas | 1.19 | 1.47 | <5 | 5 | 20 |

* NS indicates no sample collected during this period.

### REFERENCES


(*1*) PUBLIC HEALTH SERVICE. Summary of results from the raw milk sampling program, June 1957–April 1963. Rad Health Data 4:511–523 (October 1963).

(*2*) PUBLIC HEALTH SERVICE. Milk surveillance, pasteurized milk network, March 1964. Rad Health Data 5:309–317 (July 1964).

(*3*) PUBLIC HEALTH SERVICE. Milk surveillance, pasteurized milk network, December and annual summary 1964. Rad Health Data 6:193–202 (April 1965).

(*4*) MINNESOTA DEPARTMENT OF HEALTH AND RURAL COOPERATIVE POWER ASSOCIATION. Survey of Environmental Radioactivity, July 1964–December 1964. Coo–651–10 (February 1965).

(*5*) KAHN, B. et al. Rapid methods for estimating fission product concentrations in milk. Public Health Service Publication No. 999–R–2 (March 1963). Single copies available on request from Public Inquiries Branch, PHS, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

(*6*) DASGUPTA, A. K., and H. G. GREEN. A method for the radiochemical determination of iodine–131 in milk. RPD–23, Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada (October 1963).

(*7*) PORTER, C. and B. KAHN. Improved determination of strontium–90 in milk by an ion exchange method. Anal Chem 36:676–678 (March 1964).

# APPLICATION OF RADIONUCLIDE CONCENTRATIONS IN MILK TO INTAKE GUIDES, APRIL 1964–MARCH 1965

*Division of Radiological Health,*
*Public Health Service*

The concentrations of specific radionuclides in milk analyzed as part of the Pasteurized Milk Network (PMN) are reported on a monthly basis in *RHD*. In terms of radiological health surveillance activities, an important aspect of these data is the estimation of resultant radiation dose to population groups.

Approximate relationships between certain radionuclide intakes and dose have been applied to the formulation of daily intake guides (*1*) and permissible concentrations in selected environmental media (*2*). Although these guides are not themselves directly applicable to worldwide fallout, a comparison with environmental contamination levels does yield a measure of population intake. In general, intake-dose and dose-biological effect relationships used in formulating the guides cited are based on continuous intake over an entire lifetime. However, for general surveillance purposes, yearly average intakes, used with discretion, may be compared directly with the levels adopted as lifetime intake guides. Thus, the radionuclide concentrations in milk, averaged over a year's time, together with milk consumption data, might be used in conjunction with the references cited above to approximate the radiation dose to a specific population group from a specific radionuclide. Table 1 presents annual averages of radionuclide concentrations in milk sampled by the PMN. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*3*, *4*).

Total dietary intake is of prime interest, and since the intake via milk consumption constitutes only a portion of the total radionuclide intake, the relationship of milk intake to total dietary intake is of importance in evaluating milk surveillance data. The Federal Radiation Council (*5*) notes: "A number of studies have shown that conservative estimates of the strontium–90 to calcium ratio in the total diet may be made by multiplying the ratio of strontium–90 to calcium in milk in a particular locality by 1.5."[1] Thus, a rough index of the total dietary intake of strontium–90 on an annual basis may be made from PMN annual averages by using this factor and the assumptions of approximately 1.2 g of calcium per liter in PMN samples and a 1.0 g daily intake of calcium.

In the case of iodine–131, milk can be considered the major source because of the rapid distribution and consumption of fresh milk. With most other foods, normal processing and distribution times permit this short-lived nuclide to decay to insignificant levels.

The situation with respect to strontium–89 is more complicated. Its half-life of some 50 days makes it difficult to estimate the relative contribution made by sources other than milk to the total dietary intake.

The relative contribution of milk to the total dietary intake of cesium–137 is not well defined and depends principally on the amount of freshly deposited cesium–137 on products used for human and animal consumption, and the progress of cesium–137 through the food chain.

The data in table 1 are calculated as follows: results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[2] To obtain the annual average daily intake (pCi/day) of radionuclides from milk, the annual average concentration values (pCi/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

[1] This ratio may vary from 1 to 2, depending on changes in rate of fallout deposition and relative consumption of non-milk products whose contamination reflects temporal and local deposition patterns (*6*).

[2] Beginning with the October 1963 data, iodine–131 values of $<10$ pCi/liter have been considered to be zero for averaging purposes; previously, 5 pCi/liter was used for calculating the averages.

**Table 1. Average radionuclide concentrations in milk for the twelve-month periods, March 1964–February 1965 and April 1964–March 1965 [a] (pCi/liter)**

| Sampling locations | | Strontium-89 | | Strontium-90 | | Iodine-131 | | Cesium-137 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mar 1964–Feb 1965 | Apr 1964–Mar 1965 | Mar 1964–Feb 1965 | Apr 1964–Mar 1965 | Apr 1964–Feb 1965 | Apr 1964–Mar 1965 | Mar 1964–Feb 1965 | Apr 1964–Mar 1965 |
| Ala: | Montgomery | 3 | 3 | 22 | 21 | 0 | 0 | 71 | 69 |
| Alaska: | Palmer | 4 | 4 | 20 | 20 | 0 | 0 | 105 | 99 |
| Ariz: | Phoenix | 3 | 3 | 5 | 5 | 0 | 0 | 26 | 26 |
| Ark: | Little Rock | 3 | 3 | 42 | 41 | 1 | 1 | 101 | 93 |
| Calif: | Sacramento | 3 | 3 | 7 | 7 | 0 | 0 | 38 | 35 |
| | San Francisco | 3 | 3 | 9 | 9 | 0 | 0 | 40 | 38 |
| C. Z: | Cristobal | 3 | 3 | 5 | 5 | 0 | 0 | 49 | 48 |
| Colo: | Denver | 3 | 3 | 19 | 19 | 0 | 0 | 83 | 82 |
| Conn: | Hartford | 3 | 3 | 19 | 18 | 0 | 0 | 120 | 112 |
| Del: | Wilmington | 3 | 3 | 22 | 22 | 1 | 1 | 101 | 95 |
| D. C: | Washington | 3 | 3 | 19 | 19 | 0 | 0 | 71 | 67 |
| Fla: | Tampa | 3 | 3 | 15 | 15 | 0 | 0 | 227 | 222 |
| Ga: | Atlanta | 3 | 3 | 29 | 29 | 0 | 0 | 119 | 112 |
| Hawaii: | Honolulu | 3 | 3 | 12 | 12 | 0 | 0 | 76 | 74 |
| Idaho: | Idaho Falls | 4 | 4 | 24 | 25 | 0 | 0 | 135 | 127 |
| Ill: | Chicago | 3 | 3 | 18 | 18 | 0 | 0 | 99 | 94 |
| Ind: | Indianapolis | 3 | 3 | 19 | 19 | 1 | 1 | 83 | 79 |
| Iowa: | Des Moines | 4 | 4 | 24 | 24 | 0 | 0 | 75 | 71 |
| Kans: | Wichita | 4 | 3 | 20 | 20 | 0 | 0 | 58 | 56 |
| Ky: | Louisville | 3 | 3 | 28 | 27 | 0 | 0 | 70 | 64 |
| La: | New Orleans | 3 | 4 | 49 | 47 | 0 | 0 | 120 | 113 |
| Maine: | Portland | 3 | 3 | 28 | 27 | 1 | 1 | 173 | 166 |
| Md: | Baltimore | 3 | 3 | 22 | 21 | 0 | 0 | 81 | 77 |
| Mass: | Boston | 3 | 3 | 29 | 28 | 0 | 0 | 182 | 172 |
| Mich: | Detroit | 3 | 3 | 17 | 17 | 2 | 2 | 96 | 93 |
| | Grand Rapids | 3 | 3 | 20 | 20 | 1 | 1 | 107 | 103 |
| Minn: | Minneapolis | 6 | 5 | 29 | 29 | 0 | 0 | 118 | 110 |
| Miss: | Jackson | 3 | 3 | 40 | 39 | 0 | 0 | 87 | 82 |
| Mo: | Kansas City | 4 | 4 | 25 | 25 | 0 | 0 | 66 | 63 |
| | St. Louis | 4 | 4 | 21 | 21 | 0 | 0 | 66 | 62 |
| Mont: | Helena | 4 | 3 | 22 | 21 | 1 | 1 | 133 | 123 |
| Nebr: | Omaha | 3 | 3 | 24 | 23 | 0 | 0 | 77 | 73 |
| Nev: | Las Vegas | 3 | 3 | 9 | 8 | 1 | 1 | 62 | 57 |
| N. H: | Manchester | 3 | 3 | 28 | 27 | 1 | 1 | 200 | 191 |
| N. J: | Trenton | 3 | 3 | 18 | 18 | 1 | 1 | 99 | 94 |
| N. Mex: | Albuquerque | 3 | 3 | 11 | 11 | 1 | 1 | 50 | 50 |
| N. Y: | Buffalo | 3 | 3 | 19 | 19 | 0 | 0 | 120 | 115 |
| | New York | 3 | 3 | 23 | 23 | 1 | 1 | 132 | 124 |
| | Syracuse | 3 | 3 | 18 | 17 | 0 | 0 | 115 | 108 |
| N. C: | Charlotte | 3 | 3 | 36 | 36 | 0 | 0 | 97 | 93 |
| N. Dak: | Minot | 10 | 8 | 52 | 53 | 0 | 0 | 140 | 137 |
| Ohio: | Cincinnati | 3 | 3 | 21 | 20 | 0 | 0 | 76 | 73 |
| | Cleveland | 3 | 3 | 20 | 20 | 0 | 0 | 100 | 97 |
| Okla: | Oklahoma City | 3 | 3 | 21 | 21 | 0 | 0 | 59 | 57 |
| Ore: | Portland | 5 | 5 | 28 | 28 | 0 | 0 | 139 | 135 |
| Pa: | Philadelphia | 3 | 3 | 19 | 19 | 0 | 0 | 98 | 93 |
| | Pittsburgh | 3 | 3 | 28 | 28 | 0 | 0 | 127 | 122 |
| P. R: | San Juan | 3 | 3 | 12 | 12 | 0 | 0 | 69 | 66 |
| R. I: | Providence | 3 | 3 | 22 | 22 | 0 | 0 | 136 | 129 |
| S. C: | Charleston | 3 | 3 | 31 | 31 | 0 | 0 | 113 | 110 |
| S. Dak: | Rapid City | 5 | 4 | 37 | 37 | 0 | 0 | 135 | 132 |
| Tenn: | Chattanooga | 3 | 3 | 39 | 38 | 0 | 0 | 98 | 92 |
| | Memphis | 3 | 3 | 31 | 30 | 0 | 0 | 61 | 57 |
| Tex: | Austin | 3 | 3 | 8 | 8 | 0 | 0 | 35 | 34 |
| | Dallas | 3 | 3 | 19 | 18 | 0 | 0 | 51 | 48 |
| Utah: | Salt Lake City | 5 | 5 | 24 | 24 | 0 | 0 | 152 | 143 |
| Vt: | Burlington | 3 | 3 | 24 | 24 | 2 | 2 | 147 | 140 |
| Va: | Norfolk | 3 | 3 | 18 | 18 | 0 | 0 | 81 | 77 |
| Wash: | Seattle | 6 | 5 | 27 | 27 | 0 | 0 | 139 | 137 |
| | Spokane | 5 | 5 | 25 | 26 | 0 | 0 | 124 | 121 |
| W. Va: | Charleston | 3 | 3 | 24 | 23 | 0 | 0 | 63 | 58 |
| Wis: | Milwaukee | 3 | 3 | 16 | 16 | 1 | 1 | 110 | 106 |
| Wyo: | Laramie | 6 | 5 | 19 | 18 | 0 | 0 | 95 | 89 |
| Network average | | 3 | 3 | 22.7 | 22.4 | 0 | 0 | 100 | 95 |

[a] Annual averages were computed on basis of 52 weekly averages. Annual averages for barium-140 at each station were <10.
[b] Annual averages were computed on basis of 48 weekly averages.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as meteorologic conditions and dairying practices, apart from considerations of original sources of radionuclides. The moving yearly average (table 1) obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations.

## REFERENCES


(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961). Price 20 cents.

(*2*) NATIONAL COMMITTEE ON RADIATION PROTECTION. Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure, National Bureau of Standards Handbook 69, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (June 5, 1959).

(*3*) BUREAU OF CENSUS AND PUBLIC HEALTH SERVICE. National Food Consumption Survey, fresh whole milk consumption in the United States, July 1962. Rad Health Data 4:15–17 (January 1963).

(*4*) BUREAU OF CENSUS AND PUBLIC HEALTH SERVICE. Consumption of selected food items in U.S. households, July 1962. Rad Health Data 4: 124–127 (March 1963).

(*5*) FEDERAL RADIATION COUNCIL. Estimates and evaluation of fallout in the United States from nuclear weapons testing conducted through 1962, Report No. 4. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1963).

(*6*) FEDERAL RADIATION COUNCIL. Revised fallout estimates for 1964–1965 and verification of the 1963 predictions, Report No. 6. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (October 1964).

# RADIOSTRONTIUM IN CALIFORNIA MILK,[1] JANUARY 1960 THROUGH JUNE 1963

*Arnold E. Greenberg,[2] Amasa C. Cornish,[3] George S. Uyesugi,[4] and John M. Heslep[5]*

In 1960 the California State Department of Public Health, with the cooperation of a number of other State and local agencies, initiated a broad environmental radiological surveillance program. Samples of various environmental media are collected on a regular basis and analyzed for the biologically most important fission products. The purpose of this report is to describe portions of the program and to present information concerning radiostrontium in milk.

## *Sampling and analytical methods*

Initially, eight milksheds were selected for study. This number was increased to ten in early 1962. The milksheds represent different climatic and geographic areas and include those which serve the State's major population centers. Seven of the milksheds range along the Pacific coast, while the others are located in the Central Valley (figure 1). The point of sampling within each milkshed is a processing plant, which handles milk from at least a thousand cows. Depending on the status of nuclear testing and general fallout levels, sampling frequency has varied from twice per week to once per month. Each sample consists of one gallon of milk taken from a bulk tank and is preserved with four milliliters of formalin in a polyethylene bottle.

In most areas, supplemental information on environmental radioactivity is collected. This includes data from radioanalyses of airborne particulates, precipitation, dry fallout, domestic water, and sewage.

Immediately upon receipt of a milk sample in the laboratory, it is transferred to a plastic Marinelli-type beaker and counted for 100 minutes, using a 4 x 4-inch NaI (Tl) crystal coupled to a 512-channel pulse height analyzer (*1*). The gamma spectral data (0–1.8 Mev) are analyzed for barium-lanthanum–140, potassium–40, cesium–137, and iodine–131. Subsequently, the strontium in a one liter sample is precipitated as carbonate and a beta count is made for total radiostrontium. Strontium–90 is inferred by chemically separating and counting its daughter, yttrium–90. Strontium–89 is determined by subtracting stronium–90 from total radiostrontium (*2*).

The strontium–90 content of milk samples collected during the period from January 1960 through June 1963 is shown graphically by

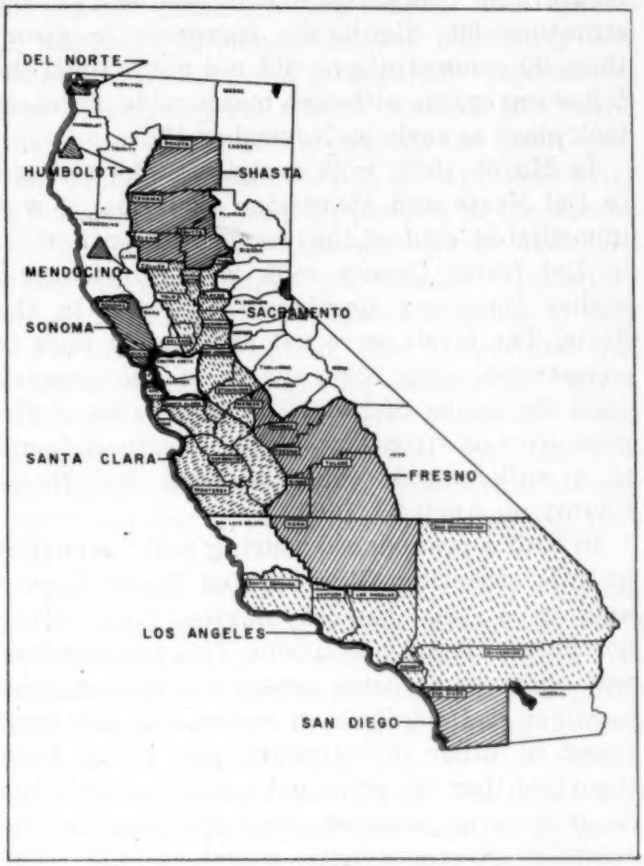


**Figure 1. California milksheds**

[1] From the Division of Laboratories and the Division of Environmental Sanitation, California State Department of Public Health.
[2] Chief, Sanitation and Radiation Laboratory.
[3] Senior Health Physicist.
[4] Research Radiochemist.
[5] Chief, Bureau of Radiological Health.

month and milkshed in figure 2. From top to bottom the milksheds are arranged as they occur geographically from north to south. Until late 1961 strontium–90 concentrations were consistently very low. The effects of resumption of nuclear testing in September 1961 were first noted in a milk sample collected in mid-October from Humboldt County which had measurable concentrations of iodine–131 and strontium–90. Significant increases in strontium–90 concentrations did not occur until the following spring although measurable increases took place as early as November 1961.

In March 1962, milk sampling was initiated in Del Norte and Mendocino Counties. It was immediately evident that levels of strontium–90 in Del Norte County milk were considerably higher than any previously observed in the State. The levels were not abnormally high in comparison with other parts of the country until the spring of 1963. The peak value of 270 picocuries of strontium–90 per liter was found in a milk sample collected from Del Norte County on April 23, 1963.

In 1962 a pronounced "spring peak" occurred in milk strontium–90 from Del Norte County and to a less marked degree from other northern California locations. This phenomenon was observed to some extent for all sampling locations in 1963. This, of course, has also been found by other investigators and it has been theorized that the principal causal factor is the occurrence of seasonal discontinuities in the stratosphere-troposphere interface (*3*). The effect is undoubtedly enhanced in areas such as northern California, where a large fraction of the annual rainfall occurs in late winter and spring.

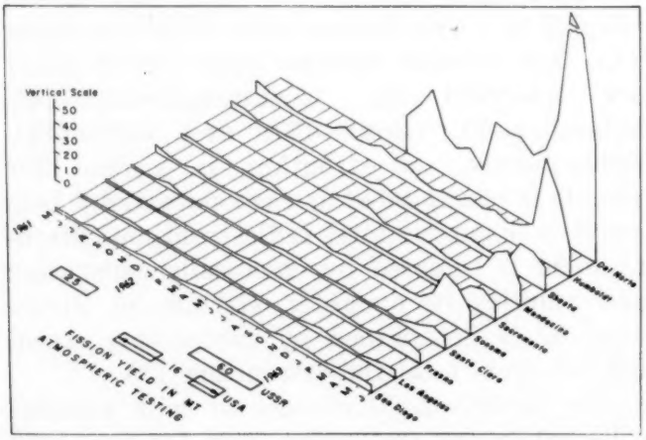


**Figure 2. Strontium–90 in California milk, pCi/liter**

Figure 3 shows the ratios of strontium–89 to strontium–90 by month for fallout and milk from Del Norte County. These data are useful in distinguishing fresh from old fission product debris and in estimating the "apparent" age of fallout material. They can also be used as an approximate internal check on the reliability of the analytical data. Since strontium–89 decays with a half-life of about 51 days, a semi-logarithmic plot of the ratios with time should demonstrate this decay rate, as in figure 3.

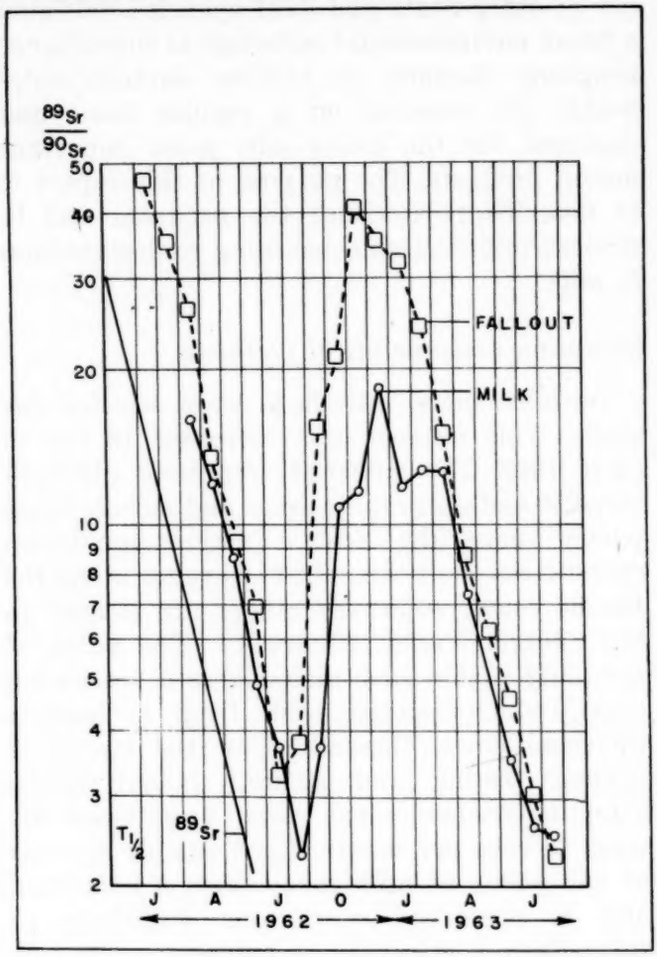


**Figure 3. Strontium–89 to strontium–90 ratio in milk and fallout, Del Norte County, California**

Table 1 gives ratios of cesium–137 to strontium–90 by month for milk from Del Norte and Humboldt Counties. The fact that over the interval of time involved these ratios remained relatively constant allowed the estimation of strontium–90 concentrations from cesium–137 measurements by gamma scan analysis. Figure 4 shows estimated strontium–90 values derived from cesium–137 values as well as the true values for strontium–90. There is no reason to believe that this empirical observation has any

**Table 1. Ratio of cesium-137 to strontium-90 in milk**

| Year | Month | Area | |
|---|---|---|---|
| | | Del Norte | Humboldt |
| 1961 | October | | 4.3 |
| | November | | 3.8 |
| | December | | 3.7 |
| 1962 | January | | 4.6 |
| | February | | 6.5 |
| | March | 5.4 | 4.6 |
| | April | 2.8 | 7.7 |
| | May | 3.4 | 5.0 |
| | June | 3.3 | 3.1 |
| | July | 2.6 | 3.3 |
| | August | 3.6 | 5.2 |
| | September | 3.3 | 4.3 |
| | October | 3.2 | 4.7 |
| | November | 3.0 | 5.0 |
| | December | 3.1 | 3.4 |
| 1963 | January | 2.1 | 2.4 |
| | February | 3.3 | 4.3 |
| | March | 3.8 | 4.0 |
| | April | 2.9 | 2.8 |
| | May | 3.2 | 3.4 |
| | June | 3.8 | 3.9 |

universal validity but the same procedure might be useful over limited time periods for any given area.

It has been repeatedly shown that global distribution of fallout is non-uniform. Peak fallout has occurred in the north temperate zone, with a maximum at approximately 42–45° N latitude (*4*). There are also strong indications of a close relationship between precipitation and deposition of fission product debris. In California, which lies between the latitudes of approximately 32° and 42°N, rainfall and fallout vary considerably on a geographical basis, both generally decreasing from north to south, as shown in table 2. It can be seen, however, that neither rainfall nor latitude differences can satisfactorily account in full for variations in observed total fallout.

## *Discussion*

In considering the strontium-90 content of milk, additional ecological and biological variables become important. Fallout components may enter the food chain either by direct foliar deposition or by plant root uptake from contaminated soil. Foliar deposition is related to the total amount and rate of fallout during the plant growing season. Root uptake is markedly influenced by soil chemistry and plant physiology, and is generally representative of longer term effects. Russell (*5*) found that foliar deposition accounted for 60–70 percent of milk strontium–90 in the first year after a test series, but only 30 percent in the second year. Other investigators have observed different percentages. A number of factors would be expected to cause such values to vary with time and location. The magnitude and relative constancy of the cesium–137/strontium–90 ratios which were observed would suggest that foliar deposition was the predominant consideration in California during 1962 and for at least the first half of 1963 (*6*).

The period covered by this study, together with the large variations found between different areas of a single State, affords an opportunity to evaluate several of the variables affecting strontium–90 in milk. During the first part of the period there was no atmospheric nuclear testing and low fallout. The latter part of the period permitted investigation of pertinent results of atmospheric testing involving some 100 megatons of fission energy.

Table 3 includes, for selected locations for 1962 and for the first six months of 1963: 1) the total picocuries of strontium–90 which

**Table 2. Latitude, annual rainfall, and total beta deposition in milkshed areas**

| Location [a] | Latitude | Mean annual rainfall | 1961 | | 1962 | | Jan.–June, 1963 | |
|---|---|---|---|---|---|---|---|---|
| | | | Rainfall | Total fallout | Rainfall | Total fallout | Rainfall | Total fallout |
| | | inches | inches | nCi/m² | inches | nCi/m² | inches | nCi/m² |
| Del Norte, Crescent City | 41°46′ | 70 | 76 | 1100 | 58 | 1490 | 39 | 1100 |
| Humboldt, Eureka | 40°48′ | 36 | 40 | 370 | 35 | 827 | 24 | 922 |
| Shasta, Redding | 40°34′ | 38 | 35 | 650 | 36 | 2050 | 25 | 1100 |
| Sonoma, Santa Rosa | 39°09′ | 29 | 21 | 336 | 28 | 785 | 18 | 724 |
| Sacramento, Sacramento | 38°31′ | 16 | — | — | 22 | 824 | 16 | 838 |
| Fresno, Fresno | 36°46′ | 9 | 7.2 | 193 | 10 | 448 | 11 | 575 |
| Los Angeles, Los Angeles | 33°56′ | 15 | 7.8 | 330 | 18 | 434 | 8.9 | 356 |
| San Diego, San Diego | 32°44′ | 11 | 5.3 | 278 | 8 | 462 | 2.6 | 202 |

[a] Data from cities listed under Location are presumed to be reasonably representative of the milksheds. This may be most in error for Del Norte where the mean annual rainfall in the milkshed area may be 15–30 percent higher than in Crescent City.

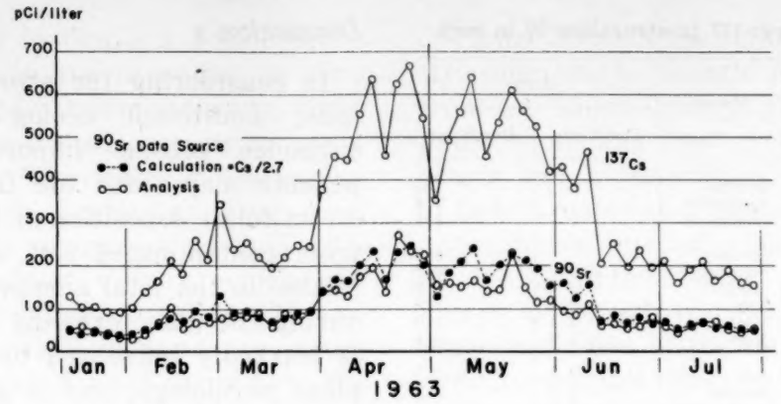


**Figure 4. Cesium–137 and strontium–90 in Del Norte milk**

would have been consumed as a consequence of drinking one liter of milk per day; 2) the total fallout strontium–90, during the same period, in picoucuries per square meter; and 3) the ratio of these two. It is readily apparent from the ratios, particularly for Del Norte County as compared with other areas of the State, that factors other than total strontium–90 fallout are of great importance in determining strontium–90 concentrations in milk. These factors must relate to the ecological and biological events between the occurrence of fallout and the appearance of strontium–90 in milk. One might expect to find an explanation on the basis of such agricultural practices as land management and cattle feeding patterns.

**Table 3. Strontium-90 in total fallout and in milk**

| Milkshed | 1962 | | | January–June 1963 | | |
|---|---|---|---|---|---|---|
| | Total pCi $^{90}Sr$ from 1 liter/day (A) | Total fallout $^{90}Sr$ pCi/m² (B) | Ratio $\frac{A}{B}$ | Total pCi $^{90}Sr$ from 1 liter/day (A) | Total fallout $^{90}Sr$ pCi/m² (B) | Ratio $\frac{A}{B}$ |
| Del Norte | 12,200 | 2,990 | 4.1 | 18,200 | 4,330 | 4.2 |
| Sonoma | 1,800 | 2,240 | 0.8 | 3,230 | 3,520 | 0.9 |
| Sacramento | 1,240 | 2,110 | 0.6 | 1,600 | 2,420 | 0.3 |
| Fresno | 960 | 2,110 | 0.5 | 1,060 | 6,320 | 0.2 |
| Los Angeles | 830 | 1,540 | 0.5 | 645 | 2,580 | 0.2 |
| San Diego | 885 | 2,890 | 0.3 | 620 | 2,420 | 0.3 |

A careful and detailed study in the St. Louis area (*7*) clearly demonstrated that wide variations in milk strontium–90 and iodine–131 from different farms in the same area could be accounted for solely by differences in land management and fertilization practices. It is suggested that milk strontium–90 concentration is inversely proportional to the weight of plant material produced per unit area of land.

The data presented in this paper cannot be used as a direct test of this statement. On the other hand, it appears reasonably logical on intuitive grounds. Field observations in northern California substantiate it qualitatively. A special study now under way in Del Norte, Humboldt, and Shasta counties has as its objectives a more detailed elucidation of factors influencing strontium–90 levels in milk and means by which such levels might be reduced by changes in agricultural practices.

*Summary and conclusions*

Data on strontium–90 in California milk from January 1960 through June 1963 have been presented and analyzed. Within the State, levels of milk strontium–90 have varied from among the lowest to the highest values reported in the United States. These differences are due in part to geographical and climatic conditions in which rainfall with its attendant burden of fission products is the single most important factor. Climate alone does not account for all the differences; agricultural practices must also play a significant role. These factors are currently under investigation.

REFERENCES

(*1*) GREENBERG, A. E. Radiation measurement and detection equipment. Rad Health News (Californinia State Department of Health) 1, 3:2–6 (1962).
(*2*) CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH. Sanitation and radiation laboratory manual. Unpublished.
(*3*) MACHTA, L. Fallout from nuclear weapons tests, Joint Congressional Committee on Atomic Energy (1959).
(*4*) ALEXANDER, L. T. and E. P. HARDY. Strontium–90 on the earth's surface. TID–6567 (1961).
(*5*) AGRICULTURAL RESEARCH COUNCIL. Agricultural Research Council Radiobiology Laboratory report, ARCRL 5 (1960).
(*6*) UNITED NATIONS; FOOD AND AGRICULTURE ORGANIZATION. Radioactive materials in food and agriculture. Atomic Energy Series No. 2 (1959).
(*7*) HANSEN, W. G., J. E. CAMPBELL, J. H. FOOKS, H. C. MITCHELL, and C. H. ELLER. Farming practices and concentrations of fission products in milk. Public Health Service Publication No. 999–R–6 (May 1964).

# RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES, OCTOBER–DECEMBER AND ANNUAL AVERAGES, 1964

*Division of Radiological Health*
*Public Health Service*

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Total Diet Sampling Network in 1961. This program is administered by the Division of Radiological Health with the assistance of the Division of Environmental Engineering and Food Protection (*1*).

The program is designed to estimate the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially the program was conducted at eight institutions; as of December 1964 its scope had increased to 46 boarding schools or institutions, distributed as shown in figure 1. These institutions range from financially well-to-do boarding schools to orphanages with severe economic limitations. All but five of the stations are located in a community where the PHS Pasteurized Milk Network collects samples; special or State milk samples are obtained from Los Angeles, California; Columbia, Mississippi; Carson City, Nevada; Sioux Falls, South Dakota; and Fargo, North Dakota.

## *Sampling procedure*

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks), obtained by duplicating the meals of a randomly selected individual each day. Each institution supplies one complete 7-day, 21-meal diet sample each month. Each daily sample is kept frozen until the end of the collection period. The total sample is packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nevada; the Southeastern Radiological Health Laboratory, Montgomery, Alabama; or the Northeastern Radiological Health Laboratory, Winchester, Massachusetts.

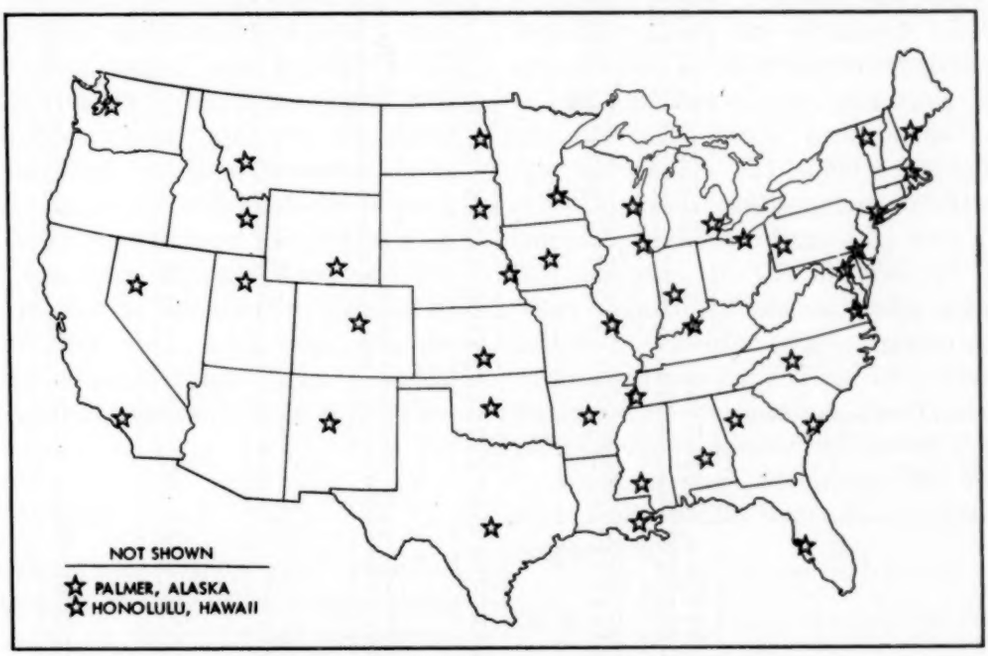


**Figure 1. Institutional diet sampling locations**

**Table 1. Institutional diet analytical results (based on a 7-day composite sample each month), fourth quarter 1964**

| Location of institution | Age (years) | Month (1964) | Dietary consumption (kg/day) | Stable elements, g/kg | | Radionuclide concentrations, pCi/kg [a] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Calcium | Potassium | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ | $^{226}Ra$ |
| Ala., Montgomery | 15–17 | Oct | 2.43 | 0.5 | 1.0 | <5 | 13 | 45 | [b] NA |
| | 15–17 | Nov | 2.17 | 0.4 | 1.2 | 10 | 15 | 45 | NA |
| | 15–17 | Dec | 2.34 | 0.5 | 1.2 | <5 | 17 | 50 | NA |
| Alaska, Palmer | 11 | Oct | 1.57 | 0.4 | 1.6 | <5 | 20 | 80 | 0.6 |
| | 10–12 | Nov | 1.62 | 0.5 | 1.1 | <5 | 14 | 75 | 0.5 |
| | 10–12 | Dec | 1.45 | 0.4 | 1.6 | <5 | 14 | 100 | 0.9 |
| Ark., Little Rock | 10–12 | Oct | 1.72 | 0.8 | 1.1 | <5 | 28 | 50 | NA |
| | 11–12 | Nov | 1.82 | 0.7 | 1.2 | <5 | 19 | 50 | NA |
| | 11–12 | Dec | 1.92 | 0.7 | 1.1 | <5 | 27 | 35 | NA |
| Calif., Los Angeles | 12–13 | Oct | 2.21 | 0.6 | 1.3 | <5 | 8 | 55 | 0.7 |
| | 12–14 | Nov | 2.03 | 0.8 | 1.7 | <5 | 8 | 20 | 0.2 |
| | 11–15 | Dec | 1.35 | 0.5 | 1.3 | <5 | 18 | 35 | 0.9 |
| Colo., Denver | 10–12 | Oct | 2.50 | 0.7 | 1.5 | <5 | 16 | 50 | 1.1 |
| | 10–12 | Nov | 2.28 | 0.8 | 1.7 | <5 | 8 | 30 | 0.6 |
| | 10–12 | Dec | 1.94 | 0.5 | 1.4 | <5 | 10 | 55 | 0.8 |
| Conn., Hartford | 15–18 | Oct | 1.82 | 0.6 | 1.3 | <5 | 8 | 70 | 0.4 |
| | 12–18 | Nov | 1.78 | 0.6 | 1.6 | <5 | 9 | 70 | 0.3 |
| | 13–18 | Dec | 1.87 | 0.7 | 1.7 | <5 | 13 | 90 | 0.8 |
| Del., Wilmington | 11–12 | Oct | 1.87 | 0.8 | 1.7 | <5 | 13 | 85 | 0.7 |
| | 11 12 | Nov | 1.94 | 0.8 | 1.6 | <5 | 13 | 65 | 0.6 |
| | 11–12 | Dec | 1.86 | 0.7 | 1.7 | <5 | 11 | 65 | 0.7 |
| Fla., Tampa | 9–12 | Oct | 2.20 | 0.7 | 1.2 | <5 | 17 | 125 | NA |
| | 10–13 | Nov | 1.90 | 0.7 | 1.4 | 5 | 16 | 140 | NA |
| | 10–12 | Dec | 2.39 | 0.8 | 1.2 | <5 | 16 | 165 | NA |
| Ga., Atlanta | 5–14 | Oct | 1.47 | 0.6 | 1.2 | 10 | 26 | 70 | NA |
| | 8–17 | Nov | 1.93 | 0.7 | 1.6 | <5 | 27 | 60 | NA |
| | 14–17 | Dec | 1.84 | 0.8 | 1.5 | <5 | 28 | 60 | NA |
| Hawaii, Honolulu | 15–17 | Oct | 1.69 | 0.6 | 1.3 | <5 | 22 | 75 | 0.6 |
| | 14–17 | Nov | 1.73 | 0.6 | 1.1 | <5 | 6 | 50 | 0.9 |
| | 15–17 | Dec | 1.49 | 0.4 | 1.4 | <5 | 12 | 105 | 0.4 |
| Idaho, Idaho Falls | 16–17 | Oct | 2.23 | 0.7 | 1.1 | <5 | 13 | 50 | [b] NA |
| | [c] | Nov | NS | NS | NS | NS | NS | NS | NS |
| | 17 | Dec | 1.65 | 0.7 | 1.5 | <5 | 16 | 100 | 1.3 |
| Ill., Chicago | 12 | Oct | 1.57 | 0.6 | 1.6 | <5 | 9 | 65 | 0.6 |
| | 11–12 | Nov | 1.40 | 0.8 | 1.4 | <5 | 12 | 70 | 0.5 |
| | 9–12 | Dec | 1.48 | 0.7 | 1.6 | <5 | 12 | 70 | 0.8 |
| Ind., Indianapolis | 10–12 | Oct | 1.56 | 0.8 | 1.5 | <5 | 11 | 55 | 0.6 |
| | 11–12 | Nov | 1.76 | 0.8 | 1.6 | <5 | 11 | 60 | 0.7 |
| | 10–12 | Dec | 1.61 | 0.7 | 1.5 | <5 | 9 | 75 | 0.6 |
| Iowa, Des Moines | 15–16 | Oct | 2.84 | 0.8 | 1.2 | 5 | 22 | 60 | NA |
| | 15–17 | Nov | 3.15 | 0.6 | 1.6 | <5 | 15 | 45 | NA |
| | 15–17 | Dec | 3.04 | 0.7 | 1.5 | <5 | 14 | 55 | NA |
| Kans., Wichita | 10 | Oct | 2.26 | 0.6 | 1.2 | <5 | 9 | 35 | NA |
| | 12 | Nov | 2.63 | 0.4 | 1.3 | <5 | 10 | 40 | NA |
| | 10 | Dec | 1.95 | 0.7 | 1.5 | <5 | 14 | 35 | NA |
| Ky., Louisville | 15–17 | Oct | 2.11 | 0.9 | 1.0 | 5 | 25 | 30 | NA |
| | 15–16 | Nov | 1.64 | 0.5 | 1.3 | <5 | 14 | 40 | NA |
| | 15–17 | Dec | 2.12 | 0.8 | 1.2 | <5 | 21 | 45 | NA |
| La., New Orleans | 15–17 | Oct | 2.48 | 0.7 | 1.2 | <5 | 22 | 50 | NA |
| | 15–17 | Nov | 2.69 | 0.6 | 1.4 | <5 | 21 | 60 | NA |
| | 15–16 | Dec | 2.60 | 0.5 | 1.3 | <5 | 25 | 45 | NA |
| Maine, Portland | 15–16 | Oct | 2.44 | 0.7 | 1.6 | <5 | 18 | 90 | 0.7 |
| | 14–15 | Nov | 2.30 | 0.8 | 1.4 | <5 | 17 | 105 | 0.8 |
| | 14 | Dec | 2.37 | 0.8 | 1.5 | <5 | 19 | 100 | 0.7 |
| Md., Baltimore | 11–12 | Oct | 1.83 | 0.6 | 1.2 | 5 | 15 | 50 | NA |
| | 11–12 | Nov | 1.93 | 0.8 | 1.6 | <5 | 15 | 50 | NA |
| | 10–12 | Dec | 1.93 | 0.7 | 1.2 | 10 | 15 | 60 | NA |
| Mass., Boston | 10–12 | Oct | 1.55 | 0.8 | 1.6 | <5 | 15 | 105 | 0.4 |
| | 10–12 | Nov | 1.55 | 0.7 | 1.3 | 5 | 16 | 90 | 0.4 |
| | 10–12 | Dec | 1.55 | 0.7 | 1.6 | <5 | 15 | 115 | 0.4 |
| Mich., Detroit | 10–12 | Oct | 1.93 | 0.8 | 1.5 | <5 | 10 | 75 | 1.1 |
| | 10–12 | Nov | 2.13 | 0.6 | 1.2 | <5 | 10 | 65 | 0.7 |
| | 11–12 | Dec | 2.04 | 0.6 | 1.4 | <5 | 12 | 70 | 0.7 |
| Miss., Columbia | 15–18 | Oct | 2.32 | 1.4 | 1.0 | <5 | 41 | 75 | NA |
| | 13–18 | Nov | 1.71 | 0.8 | 1.3 | <5 | 33 | 90 | NA |
| | 15–17 | Dec | 2.06 | 0.9 | 1.4 | 10 | 23 | 70 | NA |
| Mo., St. Louis | 15–18 | Oct | 2.34 | 0.7 | 1.6 | <5 | 22 | 55 | 1.2 |
| | 15–17 | Nov | 2.06 | 0.6 | 1.1 | <5 | 20 | 45 | 1.4 |
| | 15–17 | Dec | 1.63 | 0.5 | 1.5 | <5 | 15 | 80 | 0.5 |
| Mont., Helena | 16 | Oct | 1.52 | 0.7 | 2.0 | <5 | 14 | 65 | 0.8 |
| | 15 | Nov | 1.81 | 0.5 | 1.2 | <5 | 10 | 80 | 0.9 |
| | 15–16 | Dec | 1.60 | 0.5 | 1.2 | <5 | 12 | 80 | 0.7 |
| Nebr., Omaha | 15 | Oct | 2.28 | 0.7 | 1.5 | <5 | 16 | 40 | 0.7 |
| | 15–16 | Nov | 1.98 | 0.8 | 1.4 | <5 | 23 | 55 | 1.7 |
| | 15–18 | Dec | 1.63 | 0.5 | 1.3 | <5 | 13 | 55 | 0.4 |
| Nev., Carson City | 15–17 | Oct | 1.90 | 0.7 | 1.6 | <5 | 10 | 45 | 0.9 |
| | 15–17 | Nov | 1.72 | 0.7 | 1.4 | <5 | 10 | 55 | 0.7 |
| | 14–15 | Dec | 1.26 | 0.7 | 1.3 | <5 | 17 | 50 | 1.4 |
| N. J., Trenton | 15–17 | Oct | 2.46 | 0.6 | 1.3 | <5 | 10 | 85 | 1.2 |
| | 14–16 | Nov | 2.34 | 0.5 | 1.3 | <5 | 11 | 70 | 1.1 |
| | 15–17 | Dec | 2.32 | 0.4 | 1.6 | <5 | 10 | 10 | 1.4 |
| N. Mex., Albuquerque | 10–12 | Oct | 1.73 | 0.8 | 1.5 | <5 | 14 | 50 | 0.4 |
| | 10–12 | Nov | 1.85 | 1.7 | 1.6 | <5 | 12 | 70 | 0.6 |
| | 10–12 | Dec | 1.63 | 0.8 | 1.7 | <5 | 13 | 45 | 1.3 |
| N. Y., New York | [c] | Oct | NS | NS | NS | NS | NS | NS | NS |
| | [c] | Nov | NS | NS | NS | NS | NS | NS | NS |
| | 6–17 | Dec | 2.08 | 0.6 | 1.6 | <5 | 11 | 75 | 0.6 |
| N. C., Charlotte | 15–18 | Oct | 1.64 | 0.7 | 1.0 | 10 | 25 | 55 | NA |
| | 13–17 | Nov | 1.77 | 0.9 | 1.0 | <5 | 32 | 55 | NA |
| | 13–18 | Dec | 1.43 | 0.7 | 1.1 | <5 | 21 | 55 | NA |
| N. D., Fargo | 10–12 | Oct | 1.48 | 0.8 | 1.6 | <5 | 18 | 75 | 1.5 |
| | 10–12 | Nov | 1.46 | 0.9 | 1.3 | <5 | 14 | 70 | 0.4 |
| | 7–12 | Dec | 1.12 | 0.6 | 1.5 | <5 | 16 | 70 | 0.4 |
| Ohio, Cleveland | 10–12 | Oct | 2.03 | 0.6 | 1.5 | <5 | 12 | 65 | 0.5 |
| | 10 | Nov | 1.65 | 0.7 | 1.7 | <5 | 12 | 70 | 0.5 |
| | 10–12 | Dec | 1.56 | 0.7 | 1.4 | <5 | 12 | 60 | 0.5 |

**Table 1. Institutional diet analytical results (based on a 7-day composite sample each month), fourth quarter 1964—Continued**

| Location of institution | Age (years) | Month (1964) | Dietary consumption (kg/day) | Stable elements, g/kg | | Radionuclide concentrations, pCi/kg [a] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Calcium | Potassium | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ | $^{226}Ra$ |
| Okla., Oklahoma City | 11–14 | Oct | 1.90 | 0.8 | 1.2 | <5 | 14 | 40 | NA |
| | 11–12 | Nov | 1.73 | 0.7 | 1.5 | <5 | 16 | 45 | NA |
| | 11–12 | Dec | 1.76 | 0.8 | 1.5 | <5 | 16 | 40 | NA |
| Oreg., Portland | 13–17 | Oct | 2.41 | 0.5 | 1.5 | <5 | 11 | 55 | 0.5 |
| | 13–17 | Nov | 2.31 | 0.6 | 1.9 | <5 | 10 | 55 | 0.9 |
| | 13–17 | Dec | 1.46 | 0.4 | 2.0 | <5 | 11 | 80 | 0.7 |
| Pa., Pittsburgh | 15–16 | Oct | 1.90 | 0.7 | 1.4 | <5 | 17 | 75 | 0.8 |
| | 14–16 | Nov | 1.93 | 0.7 | 1.5 | <5 | 18 | 80 | 0.8 |
| | 14–16 | Dec | 2.10 | 0.6 | 1.5 | <5 | 14 | 70 | 0.7 |
| S. C., Charleston | 7–12 | Oct | 1.69 | 0.5 | 0.9 | <5 | 17 | 50 | NA |
| | 7–15 | Nov | 1.87 | 0.4 | 1.2 | <5 | 19 | 80 | NA |
| | (c) | Dec | NS | NS | NS | NS | NS | NS | NS |
| S. D., Sioux Falls | (c) | Oct | NS | NS | NS | NS | NS | NS | NS |
| | (c) | Nov | NS | NS | NS | NS | NS | NS | NS |
| | 10–12 | Dec | 1.62 | 0.7 | 1.8 | <5 | 19 | 90 | 0.5 |
| Tenn., Memphis | 15–16 | Oct | 1.83 | 0.6 | 1.1 | 10 | 13 | 40 | NA |
| | 15–16 | Nov | 1.34 | 0.4 | 1.0 | <5 | 16 | 25 | NA |
| | 14–17 | Dec | 1.56 | 0.6 | 1.5 | <5 | 14 | 45 | NA |
| Tex., Austin | 14–16 | Oct | 1.98 | 0.5 | 1.0 | 5 | 8 | 30 | NA |
| | 14–15 | Nov | 2.02 | 0.5 | 1.1 | <5 | 15 | 30 | NA |
| | 13–17 | Dec | 2.27 | 0.5 | 1.0 | <5 | 10 | 25 | NA |
| Utah, Salt Lake City | 12–18 | Oct | 1.05 | 0.7 | 1.5 | <5 | 15 | 75 | 1.0 |
| | 15–17 | Nov | 1.21 | 0.6 | 1.5 | <5 | 6 | 50 | 0.3 |
| | 12–18 | Dec | 1.41 | 0.5 | 1.6 | <5 | 14 | 85 | 0.6 |
| Vt., Burlington | 11–12 | Oct | 1.77 | 0.5 | 1.4 | <5 | 10 | 70 | 0.6 |
| | 11–12 | Nov | 1.60 | 0.7 | 1.7 | <5 | 13 | 75 | 1.0 |
| | 10–12 | Dec | 1.42 | 0.7 | 1.8 | <5 | 13 | 90 | 0.8 |
| Va., Norfolk | 15–16 | Oct | 2.20 | 0.5 | 1.0 | 5 | 17 | 55 | NA |
| | 14–17 | Nov | 2.20 | 0.5 | 1.0 | <5 | 20 | 60 | NA |
| | 15–17 | Dec | 2.22 | 0.5 | 1.0 | 5 | 14 | 45 | NA |
| Wash., Seattle | 15–17 | Oct | 1.69 | 0.7 | 1.7 | <5 | 15 | 85 | 0.7 |
| | 15–17 | Nov | 1.83 | 0.8 | 1.7 | <5 | 32 | 95 | 0.4 |
| | 16–17 | Dec | 1.12 | 0.5 | 1.5 | <5 | 21 | 100 | 0.4 |
| W. Va., Charleston | 10–12 | Oct | 1.92 | 0.7 | 1.3 | <5 | 20 | 65 | NA |
| | 10–12 | Nov | 1.80 | 0.7 | 1.8 | <5 | 25 | 70 | NA |
| | 10–12 | Dec | 1.76 | 0.8 | 1.2 | <5 | 27 | 70 | NA |
| Wisc., Milwaukee | 15–17 | Oct | 2.63 | 0.6 | 1.6 | <5 | 8 | 70 | 0.6 |
| | 15–17 | Nov | 2.46 | 0.7 | 1.4 | <5 | 9 | 60 | 0.6 |
| | 13–17 | Dec | 2.22 | 0.7 | 1.5 | <5 | 8 | 65 | 0.5 |
| Wyo., Laramie | 11 | Oct | 1.61 | 0.7 | 1.6 | <5 | 12 | 55 | 0.9 |
| | 11 | Nov | 1.52 | 0.7 | 1.7 | <5 | 13 | 65 | 1.1 |
| | 11 | Dec | 1.41 | 0.7 | 1.7 | <5 | 15 | 80 | NA |
| Institution average | | Oct | 1.97 | 0.7 | 1.4 | <5 | 16 | 60 | 0.8 |
| | | Nov | 1.92 | 0.7 | 1.4 | <5 | 15 | 60 | 0.7 |
| | | Dec | 1.81 | 0.6 | 1.4 | <5 | 15 | 70 | 0.7 |

[a] All barium-140 and iodine-131 levels were below the minimum detectable concentration (10 pCi/kg).
[b] NA indicates no analysis.
[c] NS indicates no sample received.

The sample for each day is packaged in three parts: (1) solid food and semi-solid food minus those portions that would not ordinarily be eaten; (2) liquid milk; (3) other beverages such as soft drinks, coffee, and tea. Drinking water is not included in these samples; however, a water sample is collected from each institution at least once a year for analysis. A record of the contents of each meal and the approximate amount of each item is made at the institution and sent with the sample. Sample volumes usually range from 6 to 16 liters; sample weights range from 8 to 20 kilograms.

### *Analytical procedures*

Because calcium compounds may have an effect on the uptake of important bone-seeking radionuclides such as strontium–89 and strontium–90 (*2*), they are included in the analytical program. Stable calcium and stable potassium determinations are obtained by conventional gravimetric or spectrophotometric methods.

The radioanalysis program is designed around three basic procedures: (1) gamma spectrometry; (2) chemical separation of strontium with subsequent counting for strontium–89 and strontium–90; and (3) radium–226 analysis. In the absence of interferences other than that from naturally occurring radioactive potassium ($^{40}K$), minimum detectable concentrations for iodine–131, cesium–137, and barium–140 by gamma spectrometry are 10 pCi/kg. Approximate minimum detectable concentrations for strontium–89, strontium–90, and radium-226 are: 5, 1, and 1 pCi/kg, respectively.

### *Data*

Table 1 gives the results of the laboratory

**Table 2. Institutional diet daily intakes (based on a 7-day composite sample each month), fourth quarter 1964**

| Location of institution | Age (years) | Month (1964) | Dietary consumption (kg/day) | Stable elements, g/day | | Radionuclide concentrations, pCi/day [a] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Calcium | Potassium | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ | $^{226}Ra$ |
| Ala., Montgomery | 15–17 | Oct | 2.43 | 1.2 | 2.4 | 5 | 32 | 110 | [b] NA |
| | 15–17 | Nov | 2.17 | 0.9 | 2.6 | 20 | 33 | 100 | NA |
| | 15–17 | Dec | 2.34 | 1.2 | 2.8 | 5 | 40 | 115 | NA |
| Alaska, Palmer | 11 | Oct | 1.57 | 0.6 | 2.5 | 5 | 31 | 125 | 1 |
| | 10–12 | Nov | 1.62 | 0.8 | 1.8 | 5 | 23 | 120 | 1 |
| | 10–12 | Dec | 1.45 | 0.6 | 2.3 | 5 | 20 | 145 | 1 |
| Ark., Little Rock | 10–12 | Oct | 1.72 | 1.4 | 1.9 | 5 | 48 | 85 | NA |
| | 11–12 | Nov | 1.82 | 1.3 | 2.2 | 5 | 35 | 90 | NA |
| | 11–12 | Dec | 1.92 | 1.3 | 2.1 | 5 | 52 | 65 | NA |
| Calif., Los Angeles | 12–13 | Oct | 2.21 | 1.3 | 2.9 | 5 | 18 | 120 | 2 |
| | 12–14 | Nov | 2.03 | 1.6 | 3.5 | 5 | 16 | 40 | 0 |
| | 11–15 | Dec | 1.35 | 0.7 | 1.8 | 5 | 24 | 45 | 1 |
| Colo., Denver | 10–12 | Oct | 2.50 | 1.8 | 3.8 | 5 | 40 | 125 | 3 |
| | 10–12 | Nov | 2.28 | 1.8 | 3.9 | 5 | 18 | 70 | 1 |
| | 10–12 | Dec | 1.94 | 1.0 | 2.7 | 5 | 19 | 105 | 2 |
| Conn., Hartford | 15–18 | Oct | 1.82 | 1.1 | 2.4 | 5 | 15 | 125 | 1 |
| | 12–18 | Nov | 1.78 | 1.1 | 2.8 | 5 | 16 | 125 | 1 |
| | 13–18 | Dec | 1.87 | 1.3 | 3.2 | 5 | 24 | 170 | 1 |
| Del., Wilmington | 11–12 | Oct | 1.87 | 1.5 | 3.2 | 5 | 24 | 160 | 1 |
| | 11–12 | Nov | 1.94 | 1.6 | 3.1 | 5 | 25 | 125 | 1 |
| | 11–12 | Dec | 1.86 | 1.3 | 3.2 | 5 | 20 | 120 | 1 |
| Fla., Tampa | 9–12 | Oct | 2.20 | 1.5 | 2.6 | 5 | 37 | 275 | NA |
| | 10–13 | Nov | 1.90 | 1.3 | 2.7 | 10 | 30 | 265 | NA |
| | 10–12 | Dec | 2.39 | 1.9 | 2.9 | 5 | 38 | 395 | NA |
| Ga., Atlanta | 5–14 | Oct | 1.47 | 0.9 | 1.8 | 15 | 38 | 105 | NA |
| | 8–17 | Nov | 1.93 | 1.4 | 3.1 | 5 | 52 | 115 | NA |
| | 14–17 | Dec | 1.84 | 1.5 | 2.8 | 5 | 52 | 110 | NA |
| Hawaii, Honolulu | 15–17 | Oct | 1.69 | 1.0 | 2.2 | 5 | 37 | 125 | 1 |
| | 14–17 | Nov | 1.73 | 1.0 | 1.9 | 5 | 10 | 85 | 2 |
| | 15–17 | Dec | 1.49 | 0.6 | 2.1 | 5 | 18 | 155 | 1 |
| Idaho, Idaho Falls | 16–17 | Oct | 2.23 | 1.6 | 2.5 | 5 | 29 | 110 | NA |
| | [c] | Nov | NS | NS | NS | NS | NS | NS | NS |
| | 17 | Dec | 1.65 | 1.2 | 2.5 | 5 | 26 | 165 | 2 |
| Ill., Chicago | 12 | Oct | 1.57 | 0.9 | 2.5 | 5 | 14 | 100 | 1 |
| | 11–12 | Nov | 1.40 | 1.1 | 2.0 | 5 | 17 | 100 | 1 |
| | 9–12 | Dec | 1.48 | 1.0 | 2.4 | 5 | 18 | 105 | 1 |
| Ind., Indianapolis | 10–12 | Oct | 1.56 | 1.2 | 2.3 | 5 | 17 | 85 | 1 |
| | 11–12 | Nov | 1.76 | 1.4 | 2.8 | 5 | 19 | 105 | 1 |
| | 10–12 | Dec | 1.61 | 1.1 | 2.4 | 5 | 14 | 120 | 1 |
| Iowa, Des Moines | 15–16 | Oct | 2.84 | 2.3 | 3.4 | 15 | 62 | 170 | NA |
| | 15–17 | Nov | 3.15 | 1.9 | 5.0 | 10 | 47 | 140 | NA |
| | 15–17 | Dec | 3.04 | 2.1 | 4.6 | 10 | 43 | 165 | NA |
| Kans., Wichita | 10 | Oct | 2.26 | 1.4 | 2.7 | 5 | 20 | 80 | NA |
| | 12 | Nov | 2.63 | 1.1 | 3.4 | 5 | 26 | 105 | NA |
| | 10 | Dec | 1.95 | 1.4 | 2.9 | 5 | 27 | 70 | NA |
| Ky., Louisville | 15–17 | Oct | 2.11 | 1.9 | 2.1 | 10 | 53 | 65 | NA |
| | 15–16 | Nov | 1.64 | 0.8 | 2.1 | 5 | 23 | 65 | NA |
| | 15–17 | Dec | 2.12 | 1.7 | 2.5 | 5 | 45 | 95 | NA |
| La., New Orleans | 15–17 | Oct | 2.48 | 1.7 | 3.0 | 5 | 55 | 125 | NA |
| | 15–17 | Nov | 2.69 | 1.6 | 3.8 | 5 | 56 | 160 | NA |
| | 15–16 | Dec | 2.60 | 1.3 | 3.4 | 5 | 65 | 115 | NA |
| Maine, Portland | 15–16 | Oct | 2.44 | 1.7 | 3.9 | 5 | 44 | 220 | 2 |
| | 14–15 | Nov | 2.30 | 1.8 | 3.2 | 5 | 39 | 240 | 2 |
| | 14 | Dec | 2.37 | 1.9 | 3.6 | 5 | 45 | 235 | 2 |
| Md., Baltimore | 11–12 | Oct | 1.83 | 1.1 | 2.2 | 10 | 27 | 90 | NA |
| | 11–12 | Nov | 1.93 | 1.5 | 3.1 | 5 | 29 | 95 | NA |
| | 11–12 | Dec | 1.93 | 1.4 | 2.3 | 20 | 29 | 115 | NA |
| Mass., Boston | 10–12 | Oct | 1.55 | 1.2 | 2.5 | 5 | 23 | 165 | 1 |
| | 10–12 | Nov | 1.55 | 1.1 | 2.0 | 10 | 25 | 140 | 1 |
| | 10–12 | Dec | 1.55 | 1.1 | 2.5 | 5 | 23 | 180 | 1 |
| Mich., Detroit | 10–12 | Oct | 1.93 | 1.5 | 2.9 | 5 | 19 | 145 | 2 |
| | 10–12 | Nov | 2.13 | 1.3 | 2.6 | 5 | 21 | 140 | 1 |
| | 11–12 | Dec | 2.04 | 1.2 | 2.9 | 5 | 24 | 145 | 1 |
| Miss., Columbia | 15–18 | Oct | 2.32 | 3.2 | 2.3 | 5 | 95 | 175 | NA |
| | 13–18 | Nov | 1.71 | 1.4 | 2.2 | 5 | 56 | 155 | NA |
| | 15–17 | Dec | 2.06 | 1.9 | 2.9 | 20 | 47 | 145 | NA |
| Mo., St. Louis | 15–18 | Oct | 2.34 | 1.6 | 3.7 | 5 | 51 | 130 | 3 |
| | 15–17 | Nov | 2.06 | 1.2 | 2.3 | 5 | 41 | 95 | 3 |
| | 15–17 | Dec | 1.63 | 0.8 | 2.4 | 5 | 24 | 130 | 1 |
| Mont., Helena | 16 | Oct | 1.52 | 1.1 | 3.0 | 5 | 21 | 100 | 1 |
| | 15 | Nov | 1.81 | 0.9 | 2.2 | 5 | 18 | 145 | 2 |
| | 15–16 | Dec | 1.60 | 0.8 | 1.9 | 5 | 19 | 130 | 1 |
| Nebr., Omaha | 15 | Oct | 2.28 | 1.6 | 3.4 | 5 | 36 | 90 | 2 |
| | 15–16 | Nov | 1.98 | 1.6 | 3.0 | 5 | 46 | 110 | 3 |
| | 15–18 | Dec | 1.63 | 0.8 | 2.1 | 5 | 21 | 90 | 1 |
| Nev., Carson City | 15–17 | Oct | 1.90 | 1.3 | 3.0 | 5 | 19 | 85 | 2 |
| | 15–17 | Nov | 1.72 | 1.2 | 2.4 | 5 | 17 | 95 | 1 |
| | 14–15 | Dec | 1.26 | 0.9 | 1.6 | 5 | 21 | 65 | 2 |
| N. J., Trenton | 15–17 | Oct | 2.46 | 1.5 | 3.2 | 5 | 25 | 210 | 3 |
| | 14–16 | Nov | 2.34 | 1.2 | 3.0 | 5 | 26 | 165 | 3 |
| | 15–17 | Dec | 2.32 | 0.9 | 3.7 | 5 | 23 | 140 | 3 |
| N. Mex., Albuquerque | 10–12 | Oct | 1.73 | 1.4 | 2.6 | 5 | 24 | 85 | 1 |
| | 10–12 | Nov | 1.85 | 3.1 | 3.0 | 5 | 22 | 130 | 1 |
| | 10–12 | Dec | 1.63 | 1.3 | 2.8 | 5 | 21 | 75 | 2 |
| N. Y., New York | [c] | Oct | NS | NS | NS | NS | NS | NS | NS |
| | [c] | Nov | NS | NS | NS | NS | NS | NS | NS |
| | 6–17 | Dec | 2.08 | 1.2 | 3.3 | 5 | 23 | 155 | 1 |
| N. C., Charlotte | 15–18 | Oct | 1.64 | 1.1 | 1.6 | 15 | 41 | 90 | NA |
| | 13–17 | Nov | 1.77 | 1.6 | 1.8 | 5 | 57 | 95 | NA |
| | 13–18 | Dec | 1.43 | 1.0 | 1.6 | 5 | 30 | 80 | NA |
| N. Dak., Fargo | 10–12 | Oct | 1.48 | 1.2 | 2.4 | 5 | 27 | 110 | 2 |
| | 10–12 | Nov | 1.46 | 1.3 | 1.9 | 5 | 20 | 100 | 1 |
| | 7–12 | Dec | 1.12 | 0.7 | 1.7 | 5 | 18 | 80 | 0 |

**Table 2. Institutional diet daily intakes (based on a 7-day composite sample each month), fourth quarter 1964—Continued**

| Location of institution | Age (years) | Month (1964) | Dietary consumption (kg/day) | Stable elements, g/day | | Radionuclide concentrations, pCi/day [a] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Calcium | Potassium | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ | $^{226}Ra$ |
| Ohio, Cleveland | 10–12 | Oct | 2.03 | 1.2 | 3.0 | 5 | 24 | 130 | 1 |
| | 10 | Nov | 1.65 | 1.2 | 2.8 | 5 | 20 | 115 | 1 |
| | 10–12 | Dec | 1.56 | 1.1 | 2.2 | 5 | 19 | 95 | 1 |
| Okla., Oklahoma City | 11–14 | Oct | 1.90 | 1.5 | 2.3 | 5 | 27 | 75 | NA |
| | 11–12 | Nov | 1.73 | 1.2 | 2.6 | 5 | 28 | 80 | NA |
| | 11–12 | Dec | 1.76 | 1.4 | 2.6 | 5 | 28 | 70 | NA |
| Oreg., Portland | 13–17 | Oct | 2.41 | 1.2 | 3.6 | 5 | 27 | 135 | 1 |
| | 13–17 | Nov | 2.31 | 1.4 | 4.4 | 5 | 23 | 125 | 2 |
| | 13–17 | Dec | 1.46 | 0.6 | 2.9 | 5 | 16 | 115 | 1 |
| Pa., Pittsburgh | 15–16 | Oct | 1.90 | 1.3 | 2.7 | 5 | 32 | 140 | 2 |
| | 14–16 | Nov | 1.93 | 1.4 | 2.9 | 5 | 35 | 155 | 2 |
| | 14–16 | Dec | 2.10 | 1.3 | 3.2 | 5 | 29 | 145 | 1 |
| S. C., Charleston | 7–12 | Oct | 1.69 | 0.8 | 1.5 | 5 | 29 | 85 | NA |
| | 7–15 | Nov | 1.87 | 0.7 | 2.2 | 5 | 36 | 150 | NA |
| S. Dak., Sioux Falls | ([c]) | Dec | NS | NS | NS | NS | NS | NS | NS |
| | ([c]) | Oct | NS | NS | NS | NS | NS | NS | NS |
| | ([c]) | Nov | NS | NS | NS | NS | NS | NS | NS |
| Tenn., Memphis | 10–12 | Dec | 1.62 | 1.1 | 2.9 | 5 | 31 | 145 | 1 |
| | 15–16 | Oct | 1.83 | 1.1 | 2.0 | 20 | 24 | 75 | NA |
| | 15–16 | Nov | 1.34 | 0.5 | 1.3 | 5 | 21 | 35 | NA |
| | 14–17 | Dec | 1.56 | 0.9 | 2.3 | 5 | 22 | 70 | NA |
| Tex., Austin | 14–16 | Oct | 1.98 | 1.0 | 2.0 | 10 | 16 | 60 | NA |
| | 14–15 | Nov | 2.02 | 1.0 | 2.2 | 5 | 30 | 60 | NA |
| | 13–17 | Dec | 2.27 | 1.1 | 2.3 | 5 | 23 | 55 | NA |
| Utah, Salt Lake City | 12–18 | Oct | 1.05 | 0.7 | 1.6 | 5 | 16 | 80 | 1 |
| | 15–17 | Nov | 1.21 | 0.7 | 1.8 | 5 | 7 | 60 | 0 |
| | 12–18 | Dec | 1.41 | 0.7 | 2.3 | 5 | 20 | 120 | 1 |
| Vt., Burlington | 11–12 | Oct | 1.77 | 0.9 | 2.5 | 5 | 18 | 125 | 1 |
| | 11–12 | Nov | 1.60 | 1.1 | 2.7 | 5 | 21 | 120 | 2 |
| | 10–12 | Dec | 1.42 | 1.0 | 2.6 | 5 | 18 | 130 | 1 |
| Va., Norfolk | 15–16 | Oct | 2.20 | 1.1 | 2.2 | 10 | 37 | 120 | NA |
| | 14–17 | Nov | 2.20 | 1.1 | 2.2 | 5 | 44 | 130 | NA |
| | 15–17 | Dec | 2.22 | 1.1 | 2.2 | 10 | 31 | 100 | NA |
| Wash., Seattle | 15–17 | Oct | 1.69 | 1.2 | 2.9 | 5 | 25 | 145 | 1 |
| | 15–17 | Nov | 1.83 | 1.5 | 3.1 | 5 | 59 | 175 | 1 |
| | 16–17 | Dec | 1.12 | 0.6 | 1.7 | 5 | 24 | 110 | 0 |
| W. Va., Charleston | 10–12 | Oct | 1.92 | 1.3 | 2.5 | 5 | 38 | 125 | NA |
| | 10–12 | Nov | 1.80 | 1.3 | 3.2 | 5 | 45 | 125 | NA |
| | 10–12 | Dec | 1.76 | 1.4 | 2.1 | 5 | 48 | 125 | NA |
| Wisc., Milwaukee | 15–17 | Oct | 2.63 | 1.6 | 4.2 | 5 | 21 | 185 | 2 |
| | 15–17 | Nov | 2.46 | 1.7 | 3.4 | 5 | 22 | 150 | 1 |
| | 13–17 | Dec | 2.22 | 1.6 | 3.3 | 5 | 18 | 145 | 1 |
| Wyo., Laramie | 11 | Oct | 1.61 | 1.1 | 2.6 | 5 | 19 | 90 | 1 |
| | 11 | Nov | 1.52 | 1.1 | 2.6 | 5 | 20 | 100 | 2 |
| | 11 | Dec | 1.41 | 1.0 | 2.4 | 5 | 21 | 115 | NA |
| Institution Average | | Oct | 1.97 | 1.3 | 2.6 | 5 | 31 | 120 | 2 |
| | | Nov | 1.92 | 1.3 | 2.7 | 5 | 30 | 120 | 1 |
| | | Dec | 1.81 | 1.2 | 2.6 | 5 | 28 | 125 | 1 |

[a] All barium-140 and iodine-131 analyses indicate levels below detection limits.
[b] NA indicates no analysis.
[c] NS indicated no sample received.

analyses of the food samples collected during October through December 1964. Stable elements are reported in grams per kilogram of diet, and radionuclide concentrations are expressed as picocuries per kilogram of diet.

Table 2 presents the dietary intake data expressed on a per-day basis from October through December 1964 for the 46 institutions from which samples were received. The intake values in this table were obtained by multiplying the food consumption rate in kg/day times the concentration values in grams or picocuries per kilogram of diet (given in table 1). Also contained in the table is the range of ages of the children from which samples are being obtained. The reported radionuclide concentrations of these samples are corrected for radioactive decay to the midpoint of the sample collection period where applicable.

Certain of the radiochemical results are reported by the laboratories as being "less-than" (<) a specified value. For data computations "less-than" values were interpreted as zero for <10 pCi/kg values for iodine–131 and barium–140 and 2.5 pCi/kg for strontium–90, and <5 pCi/kg of strontium–89.

From table 1 it is seen that for the last quarter of 1964 the average food intake ranged from 1.05 to 3.15 kg/day with an average of 1.90 kg/day.

From table 2 it is seen that the calcium intake ranged from 0.5 to 3.2 g/day with the network average being 1.3 g/day. Potassium intake ranged from 1.3 to 5.0 g/day around an average of 2.6 g/day.

Strontium–89 intakes ranged from 5 to 20 pCi/day with an average of 5 pCi/day. The strontium–90 intakes during this quarter

averaged 30 pCi/day and ranged from 7 to 95 pCi/day. The daily intake was greater than 62 pCi/day at only one station. Applicable guidance given by the Federal Radiation Council (FRC) Range II for strontium–89 is 200 to 2000 pCi/day. The FRC Range II for strontium–90 is 20 to 200 pCi/day (*3*).

Although the intake of cesium–137 ranged from 35 to 395 pCi/day, the network average for October to December 1964 remained around 120 pCi/day. The high value was observed in Tampa, Florida, reflecting continuing higher cesium–137 levels in Florida milk relative to the national average.

During this quarter, both barium–140 and iodine–131 concentrations were below detectable levels.

### *Annual averages*

Annual average radionuclide concentrations in 1964 institutional total diet samples are given in table 3. Table 4 presents the annual average radionuclide intakes as determined for 1964 by the Institutional Total Diet Sampling Network. The annual average daily intake varied from 1.39 to 2.58 kg/day, with a mean of 1.93 kg/day. Annual average calcium intakes ranged from 0.8 to 1.9 grams per day, with a mean of 1.2 grams/day. Potassium annual average daily intakes ranged from 1.9 to 3.7 grams per day with a mean of 2.6 grams per day.

Annual average daily intakes of strontium–89 in 1964 ranged from 0 to 15 pCi/day with an overall average of 5 pCi/day. These values

**Table 3. Annual average calcium, potassium, and radionuclide concentrations in institutional dietary analysis program, 1964**

| Location of institution | Total wgt. (kg./day) | (grams per kg) | | Radionuclide concentrations, pCi/kg [a] | | | |
|---|---|---|---|---|---|---|---|
| | | Calcium | Potassium | $^{89}$Sr | $^{90}$Sr | $^{137}$Cs | $^{226}$Ra |
| Ala., Montgomery [c] | 2.23 | 0.5 | 1.1 | <5 | 13 | 45 | NA |
| Alaska, Palmer | 1.50 | 0.6 | 1.4 | <5 | 20 | 105 | 0.7 |
| Ark., Little Rock | 1.79 | 0.6 | 1.2 | <5 | 26 | 65 | [b] 1.9 |
| Calif., Los Angeles | 1.79 | 0.6 | 1.6 | <5 | 19 | 50 | 0.6 |
| Colo., Denver | 2.42 | 0.6 | 1.5 | <5 | 13 | 60 | 0.7 |
| Conn., Hartford [c] | 1.86 | 0.6 | 1.5 | <5 | 11 | 80 | 0.5 |
| Del., Wilmington | 1.88 | 0.8 | 1.6 | <5 | 16 | 90 | 0.6 |
| Fla., Tampa | 2.16 | 0.7 | 1.2 | <5 | 14 | 135 | [b] 1.9 |
| Ga., Atlanta | 2.01 | 0.5 | 1.2 | <5 | 20 | 60 | [b] 1.1 |
| Hawaii, Honolulu | 1.71 | 0.5 | 1.3 | 5 | 11 | 70 | 0.9 |
| Idaho, Idaho Falls | 1.94 | 0.6 | 1.5 | <5 | 24 | 125 | 0.6 |
| Ill., Chicago [c] | 1.57 | 0.7 | 1.5 | <5 | 14 | 90 | 0.5 |
| Ind., Indianapolis [c] | 1.69 | 0.8 | 1.6 | <5 | 13 | 65 | 0.7 |
| Iowa, Des Moines [c] | 2.56 | 0.7 | 1.2 | <5 | 19 | 55 | NA |
| Kans., Wichita [c] | 2.12 | 0.6 | 1.3 | <5 | 13 | 50 | NA |
| Ky., Louisville [c] | 1.95 | 0.7 | 1.1 | <5 | 20 | 40 | NA |
| La., New Orleans | 2.58 | 0.6 | 1.4 | <5 | 26 | 90 | [b] 2.4 |
| Maine, Portland | 2.29 | 0.7 | 1.5 | <5 | 20 | 120 | 0.6 |
| Md., Baltimore [c] | 1.96 | 0.7 | 1.3 | <5 | 18 | 60 | NA |
| Mass., Boston | 1.69 | 0.7 | 1.6 | <5 | 20 | 150 | 0.4 |
| Mich., Detroit [c] | 2.01 | 0.7 | 1.4 | <5 | 12 | 75 | 0.8 |
| Minn., Minneapolis | 1.74 | 0.5 | 1.4 | 5 | 18 | 90 | 0.7 |
| Miss., Columbia | 1.97 | 0.9 | 1.3 | 5 | 31 | 125 | [b] 3.0 |
| Mo., St. Louis | 2.43 | 0.6 | 1.4 | 5 | 19 | 60 | 0.9 |
| Mont., Helena | 2.02 | 0.5 | 1.2 | <5 | 15 | 90 | 0.6 |
| Nebr., Omaha | 2.03 | 0.8 | 1.4 | <5 | 19 | 70 | 0.8 |
| Nev., Carson City [c] | 1.82 | 0.6 | 1.4 | <5 | 15 | 50 | 0.8 |
| N. J., Trenton [c] | 2.36 | 0.5 | 1.3 | <5 | 11 | 65 | 1.2 |
| N. Mex., Albuquerque | 1.92 | 0.8 | 1.5 | <5 | 13 | 45 | 0.7 |
| N. Y., New York | 1.74 | 0.8 | 1.6 | <5 | 15 | 100 | 0.7 |
| N. C., Charlotte [c] | 1.75 | 0.7 | 1.1 | <5 | 25 | 55 | NA |
| N. Dak., Fargo [c] | 1.39 | 0.8 | 1.4 | <5 | 16 | 90 | 1.0 |
| Ohio, Cleveland | 1.95 | 0.6 | 1.6 | <5 | 13 | 85 | 0.5 |
| Okla., Oklahoma City | 1.78 | 0.6 | 1.2 | <5 | 14 | 45 | [b] 2.2 |
| Oreg., Portland [c] | 2.05 | 0.4 | 1.5 | <5 | 13 | 60 | 0.6 |
| Pa., Pittsburgh | 2.17 | 0.6 | 1.5 | <5 | 17 | 85 | 0.7 |
| S. C., Charleston [c] | 1.69 | 0.5 | 1.2 | <5 | 17 | 70 | NA |
| S. Dak., Sioux Falls [d] | 1.62 | 0.7 | 1.8 | <5 | 19 | 90 | 0.5 |
| Tenn., Memphis | 1.60 | 0.6 | 1.2 | <5 | 20 | 50 | [b] 1.9 |
| Tex., Austin | 1.95 | 0.5 | 1.1 | <5 | 10 | 35 | [b] 1.5 |
| Utah, Salt Lake City | 1.42 | 0.6 | 1.5 | <5 | 18 | 110 | 0.7 |
| Vt., Burlington | 1.56 | 0.6 | 1.6 | <5 | 16 | 100 | 0.7 |
| Va., Norfolk [c] | 2.19 | 0.5 | 1.1 | <5 | 15 | 60 | [b] 2.0 |
| Wash., Seattle | 1.90 | 0.6 | 1.5 | 5 | 22 | 105 | 0.7 |
| W. Va., Charleston [c] | 1.90 | 0.6 | 1.2 | <5 | 23 | 60 | NA |
| Wisc., Milwaukee | 2.50 | 0.7 | 1.5 | <5 | 11 | 80 | 0.5 |
| Wyo., Laramie | 1.63 | 0.6 | 1.5 | <5 | 18 | 70 | [e] 1.0 |
| Institutional Average | 1.93 | 0.6 | 1.4 | <5 | 17 | 75 | 0.7 |
| Maximum | 2.58 | 0.9 | 1.8 | 5 | 31 | 150 | 1.2 |
| Minimum | 1.39 | 0.4 | 1.1 | <5 | 10 | 35 | 0.4 |

[a] NA indicates no analysis performed.
[b] Total radium.
[c] Average $^{90}$Sr and $^{137}$Cs concentrations are minimum values. Station began operation in June 1964 or later. Peak values for these nuclides were observed during the second quarter of 1964.
[d] Data for this station based on December 1964 sample only.
[e] Average based on radium-226 only.

**Table 4. Annual average calcium, potassium, and radionuclide intakes as determined by institutional total diet sampling, 1964**

| Location of institution | Total wgt. (kg./day) | (grams per day) | | Radionuclide concentrations, pCi/day | | | |
|---|---|---|---|---|---|---|---|
| | | Calcium | Potassium | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ | $^{226}Ra$ |
| Ala., Montgomery [c] | 2.23 | 1.1 | 2.4 | 10 | 30 | 105 | [a] NA |
| Alaska, Palmer | 1.50 | 0.8 | 2.1 | 10 | 30 | 155 | 1 |
| Ark., Little Rock | 1.79 | 1.1 | 2.1 | 5 | 47 | 110 | [b] 3.5 |
| Calif., Los Angeles | 1.79 | 1.2 | 2.8 | 5 | 17 | 90 | 1 |
| Colo., Denver | 2.42 | 1.5 | 3.7 | 10 | 31 | 150 | 2 |
| Conn., Hartford [c] | 1.86 | 1.2 | 2.8 | 5 | 20 | 150 | 1 |
| Del., Wilmington | 1.88 | 1.5 | 3.0 | 5 | 29 | 175 | 1 |
| Fla., Tampa | 2.16 | 1.5 | 2.6 | 5 | 29 | 295 | [b] 4.3 |
| Ga., Atlanta | 2.01 | 1.0 | 2.3 | 10 | 38 | 120 | [b] 3.4 |
| Hawaii, Honolulu | 1.71 | 0.8 | 2.3 | 10 | 18 | 125 | 2 |
| Idaho, Idaho Falls | 1.94 | 1.3 | 3.0 | 5 | 46 | 240 | 1 |
| Ill., Chicago [c] | 1.57 | 1.1 | 2.4 | 5 | 21 | 140 | 1 |
| Ind., Indianapolis [c] | 1.69 | 1.3 | 2.6 | 5 | 22 | 110 | 1 |
| Iowa, Des Moines [c] | 2.56 | 1.9 | 3.2 | 10 | 47 | 145 | NA |
| Kans., Wichita [c] | 2.12 | 1.3 | 2.7 | 5 | 27 | 100 | NA |
| Ky., Louisville [c] | 1.95 | 1.4 | 2.2 | 5 | 40 | 80 | NA |
| La., New Orleans | 2.58 | 1.6 | 3.5 | 10 | 67 | 225 | [b] 6.3 |
| Maine, Portland | 2.29 | 1.6 | 3.4 | 5 | 45 | 270 | 1 |
| Md., Baltimore [c] | 1.96 | 1.4 | 2.5 | 10 | 35 | 120 | NA |
| Mass., Boston | 1.69 | 1.2 | 2.6 | 5 | 34 | 260 | 1 |
| Mich., Detroit [c] | 2.01 | 1.4 | 2.8 | 5 | 23 | 155 | 1 |
| Minn., Minneapolis | 1.74 | 0.9 | 2.5 | 10 | 32 | 160 | 1 |
| Miss., Columbia | 1.97 | 1.8 | 2.5 | 10 | 62 | 245 | [b] 6.1 |
| Mo., St. Louis | 2.43 | 1.6 | 3.4 | 15 | 48 | 150 | 2 |
| Mont., Helena | 2.02 | 1.0 | 2.4 | 10 | 30 | 190 | 1 |
| Nebr., Omaha | 2.03 | 1.6 | 2.9 | 5 | 39 | 140 | 2 |
| Nev., Carson City [c] | 1.82 | 1.2 | 2.6 | 5 | 28 | 90 | 1 |
| N. J., Trenton [c] | 2.36 | 1.1 | 3.1 | 5 | 26 | 150 | 3 |
| N. Mex., Albuquerque | 1.92 | 1.6 | 2.9 | 5 | 24 | 80 | 1 |
| N. Y., New York | 1.74 | 1.4 | 2.8 | 0 | 27 | 170 | 1 |
| N. C., Charlotte [c] | 1.75 | 1.2 | 1.9 | 5 | 45 | 95 | NA |
| N. Dak., Fargo [c] | 1.39 | 1.1 | 2.0 | 5 | 22 | 125 | 1 |
| Ohio, Cleveland | 1.95 | 1.2 | 3.2 | 5 | 26 | 170 | 1 |
| Okla., Oklahoma City | 1.78 | 1.1 | 2.1 | 5 | 24 | 75 | [b] 4.2 |
| Oreg., Portland [c] | 2.05 | 0.9 | 3.0 | 5 | 26 | 125 | 1 |
| Pa., Pittsburgh | 2.17 | 1.3 | 3.2 | 5 | 36 | 185 | 2 |
| S. C., Charleston [c] | 1.69 | 0.8 | 1.9 | 5 | 29 | 120 | NA |
| S. Dak., Sioux Falls [d] | 1.62 | 1.1 | 2.9 | 5 | 31 | 145 | 1 |
| Tenn., Memphis | 1.60 | 1.0 | 2.0 | 5 | 32 | 80 | [b] 3.0 |
| Tex., Austin | 1.95 | 1.0 | 2.1 | 5 | 20 | 70 | 2.9 |
| Utah, Salt Lake City | 1.42 | 0.9 | 2.2 | 5 | 26 | 155 | 1 |
| Vt., Burlington | 1.56 | 1.0 | 2.5 | 5 | 25 | 155 | 1 |
| Va., Norfolk [c] | 2.19 | 1.1 | 2.4 | 10 | 34 | 130 | [b] 4.3 |
| Wash., Seattle | 1.90 | 1.2 | 2.8 | 10 | 43 | 200 | 1 |
| W. Va., Charleston [c] | 1.90 | 1.2 | 2.3 | 5 | 43 | 115 | NA |
| Wisc., Milwaukee | 2.50 | 1.5 | 3.2 | 5 | 24 | 170 | 1 |
| Wyo., Laramie | 1.63 | 1.0 | 2.4 | 5 | 30 | 115 | [e] 2 |
| Institutional Average | 1.93 | 1.2 | 2.6 | 5 | 33 | 145 | 1 |
| Maximum | 2.58 | 1.9 | 3.7 | 15 | 67 | 295 | 3 |
| Minimum | 1.39 | 0.8 | 1.9 | 0 | 17 | 75 | 1 |

[a] NA indicates no analysis performed.
[b] Total radium.
[c] Average $^{90}Sr$ and $^{137}Cs$ concentrations are minimum values. Station began operation in June 1964 or later. Peak values for these nuclides were observed during the second quarter of 1964.
[d] Data for this station based on December 1964 sample only.
[e] Average based on radium-226 only.

are within the FRC Range I (*3*), which indicates that periodic confirmatory surveillance is the recommended action.

The strontium–90 annual average daily intake ranged from 17 to 67 pCi/day and the overall average daily intake was 33 pCi/day. These results fall within FRC Range II (*3*), indicating that quantitative surveillance and routine control is the recommended action.

Cesium–137 daily intakes ranged from 70 to 295 pCi/day with an average of 145 pCi/day. At the same time radium–226 daily intakes averaged 1 pCi/day.

During 1964, both barium–140 and iodine–131 concentrations were below detectable levels.

## REFERENCES


(*1*) ANDERSON, E. C. and D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(*2*) CHEN, P. S., JR., A. R. TEREPKA, and H. C. HODGE. The pharmacology and toxicology of the bone seekers. Ann Rev Pharmacol 1:369–396 (1961).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards. Report No. 2, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (September 1961), price 20 cents.


Recent coverage in *Radiological Health Data:*

| *Period* | *Issue* |
|---|---|
| July–September 1963 | *March 1964* |
| October–December 1963 | *July 1964* |
| January–March 1964 | *October 1964* |
| April–June 1964 | *January 1965* |
| July–September 1964 | *April 1965* |

# RADIONUCLIDES IN DIETS FOR TEENAGERS FEBRUARY–NOVEMBER 1964

*Division of Pharmacology, Food and Drug Administration*

It has been estimated that among all age groups 16 to 19-year-old males need more food daily than any other segment of the U.S. population (*1*). Because of this, the Food and Drug Administration (FDA) chose this age group for a test of the maximum radionuclide intake of all population groups. As a basis for the test, the food plan used was that recommended by the U.S. Department of Agriculture (USDA) for a nutritionally adequate diet at moderate cost level for boys 16–19 years of age (*2*).

The FDA study of radionuclides in diets for teenagers was begun on a pilot basis in May 1961 in the Washington, D.C. area. Since then, the program has been expanded to include 8 other cities—San Francisco, Minneapolis, St. Louis, Atlanta, Denver, Boston, Dallas, and Seattle.

By selecting the 16 to 19-year-old male, who daily needs 3,600 calories with adequate protein, minerals, and vitamins, compared with 3,200 calories and smaller amounts of nutrients needed by the "standard" man, the radionuclide intake in U.S. diets can be conservatively estimated. For the purposes of the sampling program, amounts of the foods selected from the 11 food groups of the USDA plan were proportioned according to the 1965 Household Food Consumption Survey (*3*).

## *Sampling and analytical procedures*

To duplicate the diet of a 19-year-old male, a list of 82 different items of food and drink was prepared. Quarterly samples of these items, covering a two-week consumption period, were purchased from national food chain stores. Efforts were made to locate the sources of the food items and to arrange representation in the samples on the broadest possible geographical basis.

The foods were prepared by professional dietitians in diet kitchens at each city in a manner comparable to domestic preparation procedures. The most acceptable home practices for washing, trimming, bone removal, and separation of wastes and cooking water were used. Representative portions of the foods (including about 8 liters of drinking water) were homogenized into a slurry, and aliquots were analyzed for strontium–90 and cesium–137 at the nearest FDA District laboratory. Strontium–90 was separated radiochemically and its concentration determined by beta counting. Gamma spectrometry was employed for cesium–137 analysis.

## *Results*

The quarterly strontium–90 and cesium–137 concentrations and daily intakes for the recommended diet are presented in tables 1

**Table 1. Strontium-90 concentrations and intakes in the total diet, 1964**

| Sampling locations | February 1964 | | May 1964 | | August 1964 | | November 1964 | |
|---|---|---|---|---|---|---|---|---|
| | pCi/kg | pCi/day [a] | pCi/kg | pCi/day | pCi/kg | pCi/day | pCi/kg | pCi/day |
| Calif: San Francisco | 7.0 | 26 | 7.0 | 26 | 6.3 | 24 | 5.9 | 22 |
| Colo: Denver | 12 | 45 | 14 | 52 | 11 | 40 | 7.2 | 27 |
| D. C: Washington | 17 | 63 | 15 | 57 | 11 | 42 | [b] NS | NS |
| Ga: Atlanta | 25 | 92 | 28 | 103 | 20 | 75 | 21 | 79 |
| Mass: Boston | [c] NA | NA | 7.0 | 26 | 17 | 63 | 8.4 | 32 |
| Minn: Minneapolis | 13 | 50 | 12 | 47 | 10 | 38 | 8.8 | 33 |
| Mo: St. Louis | 10 | 38 | 15 | 56 | 18 | 67 | 7.6 | 29 |
| Texas: Dallas | 13 | 48 | 14 | 52 | 11 | 41 | 10 | 3.8 |
| Wash: Seattle | 13 | 48 | 17 | 65 | 13 | 48 | 14 | 53 |
| Average | 14 | 53 | 14 | 53 | 13 | 53 | 11 | 41 |

[a] Intakes based on the consumption of 3.76 kg food and drink for the 16–19-year-old male.
[b] NS indicates no sample found.
[c] NA indicates no analysis performed.

**Table 2. Cesium-137 concentrations and intakes in the total diet, 1964**

| Sampling locations | February 1964 | | May 1964 | | August 1964 | | November 1964 | |
|---|---|---|---|---|---|---|---|---|
| | pCi/kg | pCi/day [a] | pCi/kg | pCi/day | pCi/kg | pCi/day | pCi/kg | pCi/day |
| Calif: San Francisco | 63 | 237 | 63 | 237 | 34 | 128 | 43 | 162 |
| Colo: Denver | 70 | 263 | 84 | 316 | 59 | 222 | 37 | 139 |
| D. C: Washington | 82 | 308 | 97 | 364 | 59 | 222 | [b] NS | NS |
| Ga: Atlanta | 91 | 342 | 125 | 470 | 51 | 192 | 83 | 312 |
| Mass: Boston | 119 | 447 | 108 | 406 | 92 | 346 | 96 | 361 |
| Minn: Minneapolis | 103 | 387 | 87 | 327 | 102 | 384 | 68 | 256 |
| Mo: St. Louis | 67 | 252 | 83 | 312 | 39 | 147 | 55 | 207 |
| Texas: Dallas | [c] NA | NA | 56 | 211 | 40 | 150 | 56 | 211 |
| Wash: Seattle | 64 | 241 | 104 | 391 | 86 | 323 | 97 | 365 |
| Average | 82 | 309 | 89 | 335 | 70 | 263 | 67 | 252 |

[a] Intakes based on the consumption of 3.76 kg food and drink for the 16–19-year-old male.
[b] NS indicates no sample found.
[c] NA indicates no analysis performed.

and 2. Individual station values for the quarter ending in the month shown are given along with network averages for the nine cities sampled.

*Strontium–90*

The network average daily strontium–90 intakes for March 1961 through November 1964 are presented in figure 1. Ranges are shown where appropriate. Prior to May 1962, only one location was sampled. The average strontium–90 intake in the diet is seen to have increased steadily from 14 pCi/day in May 1961 to 63 pCi/day in February 1964, after which a decrease is noted. The figure also shows that strontium–90 contamination resulting from the USSR and USA atmospheric tests of 1961 and 1962 has peaked broadly over the years 1963 and 1964; however, a downward trend is apparent. The peak average value in February 1964 represents about one-third of the top of Range II (200 pCi/day) as recommended by the Federal Radiation Council (*4*).

The dotted lines in figure 1 represent the daily intakes observed in Atlanta, Georgia, and San Francisco, California. Comparison of these values with the observed ranges of daily strontium–90 intakes indicates that the Atlanta

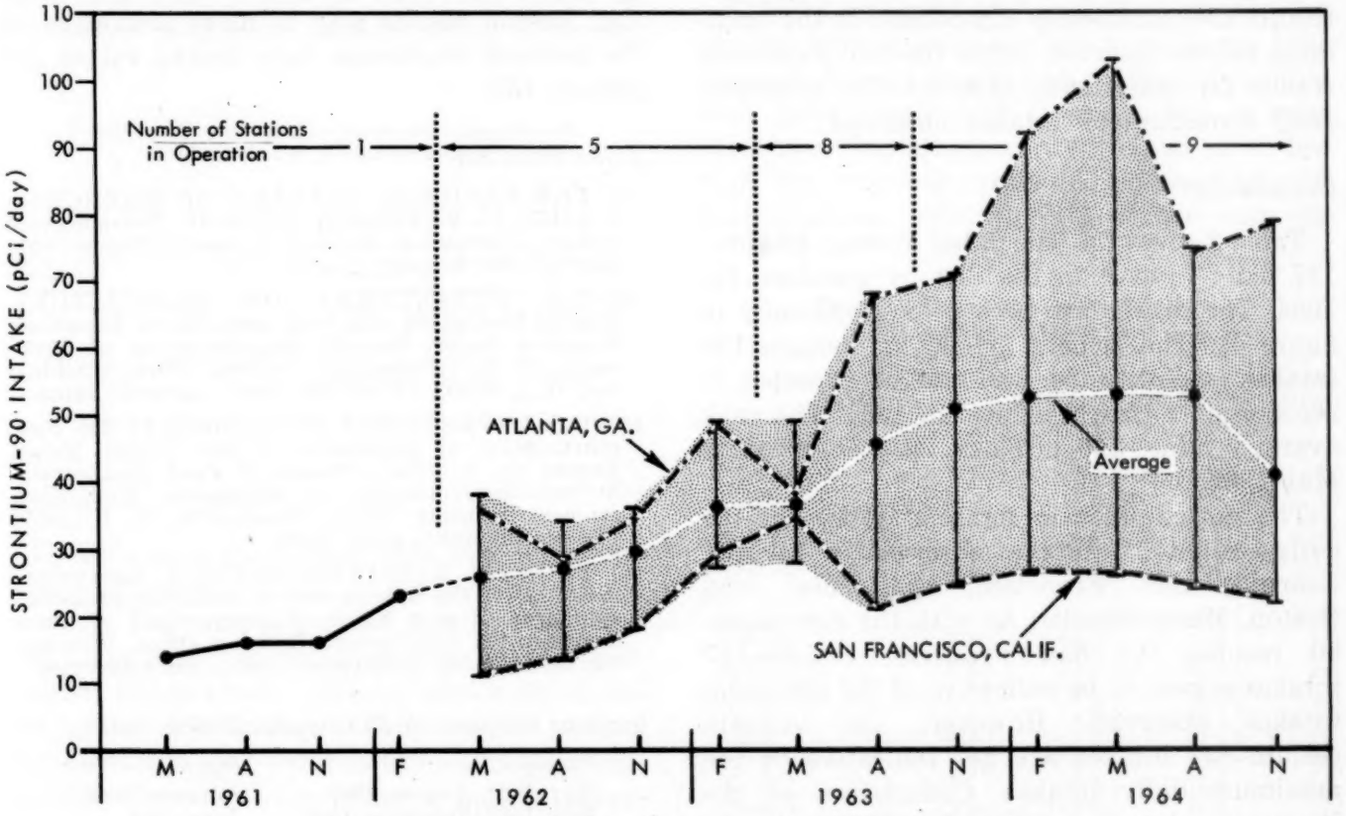


**Figure 1. Averages and ranges of daily strontium–90 intake in FDA teenage standard diet**

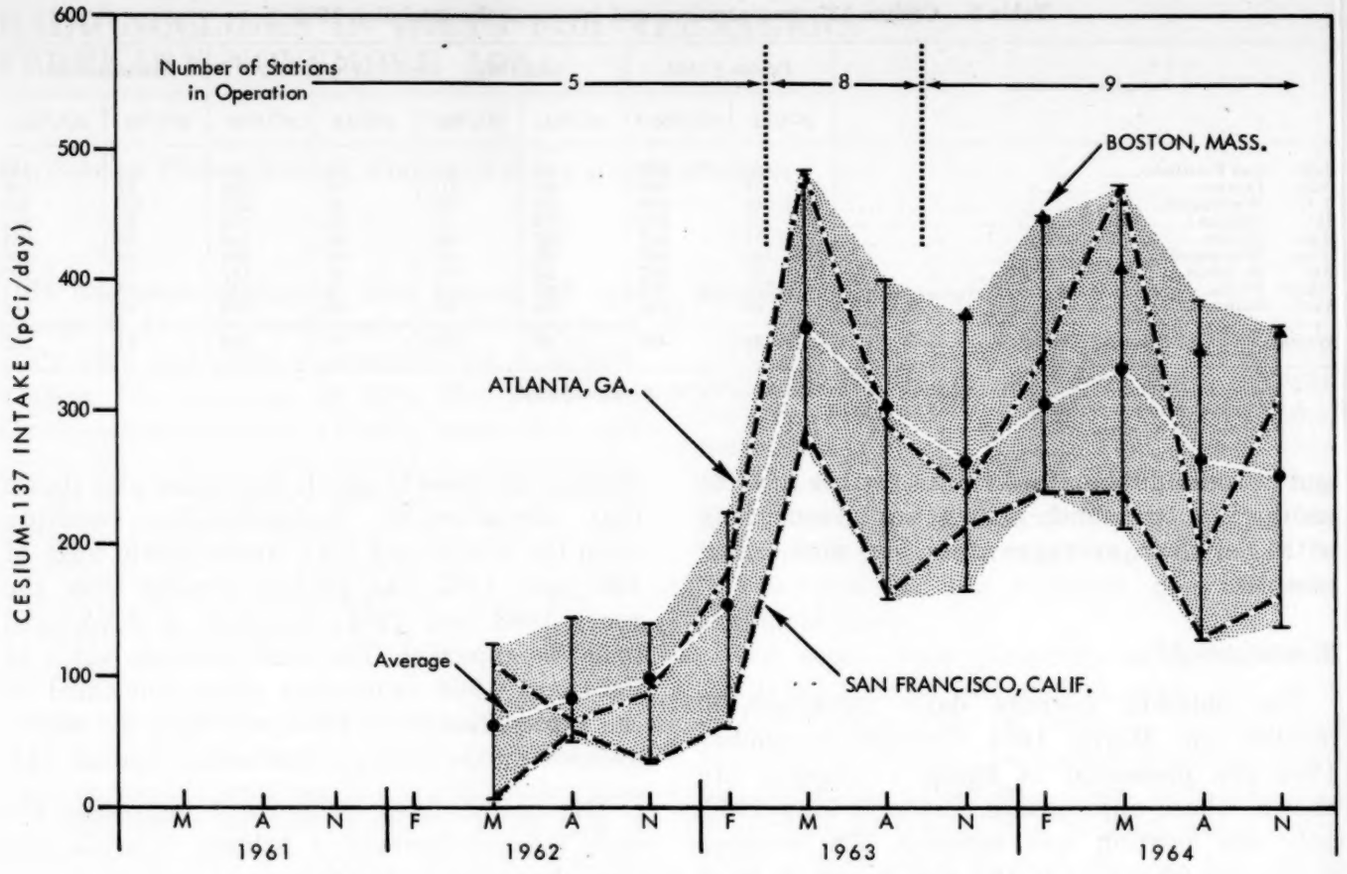


**Figure 2. Averages and ranges of daily cesium–137 intake in FDA teenage standard diet**

results are consistently comparable to the maximum values observed, while the San Francisco results are consistently typical of the minimum daily strontium–90 intakes observed.

*Cesium–137*

Table 2 gives the calculated average cesium–137 daily intakes in the diet by quarters for 1964. The results are presented graphically in figure 2. The general trend in cesium–137 intakes is downward, and can be expected to become more clearly defined in 1965. The peak average value, 366 pCi/day, was observed in May 1963.

The dotted lines in figure 2 represent the daily cesium–137 intakes observed in Atlanta, Georgia; San Francisco, California; and Boston, Massachusetts. As with the strontium–90 results, the San Francisco cesium–137 intakes appear to be indicative of the minimum intakes observed. However, the Atlanta cesium–137 intakes are not indicative of the maximum daily intakes. Comparison of the Boston results since November 1963 suggests that Boston results may be more indicative of the network maximum daily intake values for cesium–137.

REFERENCES

(*1*) THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL. Recommended dietary allowances, National Research Council Publication 589, Revised (1958).

(*2*) U.S. DEPARTMENT OF AGRICULTURE. Family food plans and food costs, Home Economics Research Report No. 20, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (November 1962), price 35 cents.

(*3*) U.S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, Report No. 1 (1955), Household Food Consumption Survey, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (December 1956), price $1.25.

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (September 1961), price 20 cents.

Previous coverage in *Radiological Health Data:*

| *Period* | *Issue* |
|---|---|
| May 1961–August 1962 | *January 1963* |
| May 1962–February 1963 | *June 1963* |
| May 1963–November 1963 | *April 1964* |

# ESTIMATED DAILY INTAKE OF RADIONUCLIDES IN CONNECTICUT STANDARD DIET, MARCH 1963–DECEMBER 1964

*Connecticut State Department of Health*

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. These analyses included strontium–89, strontium–90, and gamma emitting radionuclides.

The standard diet was selected to represent the food intake of an 18-year-old boy for one day (table 1). The total weight of the complete blended diet averaged 3 kilograms, including milk and dairy products. Any raw fruit or vegetables used were washed before blending.

**Table 1. Representative kinds and amounts of foods included in standard diet**

| | |
|---|---|
| Bread, white—8 slices | Ice Cream—½ pint |
| Butter, ½ stick | Lettuce, washed—4–5 leaves |
| Carrots, scraped—½ cup | Milk—3 cups |
| Celery, washed and trimmed—3 stalks. | Oatmeal, uncooked—43 grams |
| Cookies—4 | Orange—1 |
| Cottage Cheese—⅗ cup | Peanut Butter—2½ tablespoons |
| Cupcakes—2 | Pears, canned—2 halves with juice |
| Egg—1 | Potatoes, washed, not peeled—2 |
| Green beans, washed—½ cup | Sugar—5 tablespoons |
| Ham—85 grams | Tomato juice—113 grams |
| Hamburger—227 grams | Tuna fish, drained—43 grams |

## *Analytical procedure*

Gamma emitting radionuclide concentrations were determined using a 2-kilogram sample portion. The sample portion was counted in a low-background shield employing a 4 x 4-inch sodium iodide crystal detector and a 400-channel pulse height analyzer. The resultant gamma ray spectrum was reduced to individual radionuclide concentrations using a matrix procedure.

Strontium–89 and strontium–90 analyses were performed on a sample portion which was dried and ashed. Individual strontium results were determined by chemical separation subsequent to counting a low-background Geiger-Mueller counter utilizing a thin-window, gas-flow counting chamber.

## *Results and discussion*

Table 2 presents the analytical results for the Connecticut standard diet from March 1963 through December 1964. Radionuclides other than those listed were observed, but in most cases the concentrations were equal to or less than the counting error. In a few cases, the concentrations were slightly higher than the

**Table 2. Radionuclide concentrations in teenage standard diet**

| Month | Potassium (g/kg) | Strontium-89 (pCi/kg) | Strontium-90 (pCi/kg) | Cesium-137 (pCi/kg) |
|---|---|---|---|---|
| 1963 | | | | |
| March | 2.3 | 5.0 | 8.7 | 60 |
| July | 2.2 | 15.9 | 13.7 | 80 |
| August | 2.4 | 15.5 | 13.4 | 130 |
| September | 2.3 | 10.3 | 15.6 | 120 |
| October | 2.2 | 4.1 | 16.4 | 100 |
| November | 2.4 | 4.4 | 13.1 | 110 |
| December | 2.3 | 3.4 | 17.3 | 140 |
| 1964 | | | | |
| January | 2.3 | 4.6 | 15.1 | 140 |
| February | 2.4 | <3.0 | 13.2 | 110 |
| March | 2.2 | <3.0 | 16.4 | 150 |
| April | 2.4 | <3.0 | 14.0 | 160 |
| May | 2.4 | <3.0 | 11.9 | 90 |
| June | 2.1 | <3.0 | 16.4 | 120 |
| July | 2.0 | <3.0 | 15.1 | 130 |
| August | 2.2 | <3.0 | 19.2 | 110 |
| September | 2.4 | <3.0 | 15.4 | 100 |
| October | 2.4 | <3.0 | 14.5 | 100 |
| November | 2.1 | <3.0 | 12.0 | 80 |
| December | 2.3 | <3.0 | 12.4 | 70 |

counting error. These included ruthenium–106 in three samples (counting error ±40 pCi/kg with the matrix procedure used) and zirconium-niobium–95 in one sample (counting error ±10 pCi/kg).

Results representing the total daily intake for the radionuclides observed are presented in table 3. In order to evaluate general trends the strontium–90 and cesium–137 daily intakes are plotted as a function of time in figure 1.

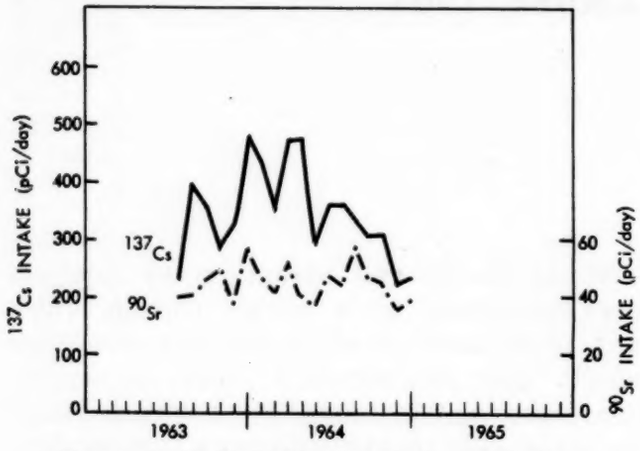


**Figure 1. Radionuclide intake in Connecticut standard diet**

The cesium–137 intake shows seasonal variation, with a maximum in the spring; the strontium–90 daily intake values have remained fairly uniform from March 1963 through December 1964.

**Table 3. Daily radionuclide intakes in Connecticut standard diet**

| Month | Potassium (g/day) | Strontium-89 (pCi/day) | Strontium-90 (pCi/day) | Cesium-137 (pCi/day) |
|---|---|---|---|---|
| 1963 | | | | |
| March | 7.6 | 16.7 | 28.9 | 200 |
| July | 6.4 | 46.1 | 39.6 | 230 |
| August | 7.2 | 43.2 | 39.9 | 390 |
| September | 6.9 | 30.8 | 46.4 | 360 |
| October | 6.5 | 12.2 | 48.7 | 280 |
| November | 6.8 | 12.4 | 37.2 | 320 |
| December | 7.7 | 11.3 | 57.6 | 480 |
| 1964 | | | | |
| January | 7.1 | 14.2 | 46.7 | 430 |
| February | 7.5 | <3.0 | 41.3 | 350 |
| March | 6.8 | <3.0 | 50.3 | 470 |
| April | 7.0 | <3.0 | 40.6 | 470 |
| May | 7.6 | <3.0 | 37.6 | 290 |
| June | 6.1 | <3.0 | 47.6 | 360 |
| July | 5.8 | <3.0 | 43.9 | 370 |
| August | 6.4 | <3.0 | 55.9 | 330 |
| September | 7.3 | <3.0 | 46.7 | 310 |
| October | 7.5 | <3.0 | 45.2 | 310 |
| November | 6.2 | <3.0 | 35.6 | 220 |
| December | 7.2 | <3.0 | 38.9 | 230 |

# ESTIMATES OF THE CONCENTRATIONS OF STRONTIUM-89, STRONTIUM-90, AND CESIUM-137 IN MILK AS A FUNCTION OF TIME AFTER AN ACUTE LOCALIZED CONTAMINATING EVENT

*Report of Ad Hoc Panel on Environmental Factors,[1] Federal Radiation Council*

The Federal Radiation Council, in developing recommendations[2] for protective actions applicable to strontium–89, strontium–90 and cesium–137, convened this Panel to examine various environmental problems related to human exposure that could occur subsequent to an acute localized contaminating event involving any of the three radionuclides. Fresh fluid milk was identified as the most important problem area because of its unique potential relative to other pathways to transmit high levels of exposure to large segments of the public in short time intervals. Particular attention, therefore, was directed to the transmission of strontium–89, strontium–90 and cesium–137 to man through the pasture-cow-fresh milk pathway of contamination.

This report primarily provides a quantitative assessment of various factors involving radioactive contamination of pasture and milk subsequent to an acute contaminating event for which prompt action may be necessary. As such quantitative assessment must be predicated on a given set of environmental factors, the following conditions of environmental contamination and milk consumption were assumed:

1. The contaminating event is a single acute intrusion involving a localized area in the order of hundreds of square miles;

2. the deposition will occur within a period of one day;

3. the previous cumulative levels of contamination in the soil or on pasture with these radionuclides are negligible relative to the levels resulting from the contaminating event;

4. the deposition occurs in a locale in which pasturage provides the major portion of the roughage consumed by the dairy cattle and during a time period when pasturage is at a normal seasonal rate of vegetative growth;

5. residents of the involved area daily consume an average of one liter of milk produced from the contaminated pasture;

6. the physical and chemical properties of strontium–89, strontium–90 and cesium–137 are the same as found in worldwide fallout.

With these assumptions, estimates are made of the theoretical concentrations and changes in concentration that can be expected to occur for each nuclide in fresh milk as a function of time following the acute contaminating event. Corresponding estimates also are made of the projected intake[3] of these nuclides by a human population whose total milk supply consists of the contaminated milk. The theoretical potential of certain protective actions to reduce the projected intakes also is considered. The estimates, for the most part, are derived from data from experimental work (appendix 1). Computations also were made from data from the PHS pasteurized milk surveillance network (appendix 2) and were in basic agreement with those derived experimentally.

Experiments were conducted with small groups of cows which were given constant daily activities of radionuclides, and the resultant levels of these nuclides were observed in milk (appendix 1). The graphs in figures 1 and 2 present curves which characterize the secretion of strontium–89, strontium–90, and

[1] The Panel contributing to this report is as follows:
Arthur H. Wolff (Chairman) — Benjamin H. Bruckner
George F. Fries — John Harley
Joseph Rivera — Tommy F. McCraw
Jared J. Davis — Frank B. Hungate
F. W. Lengemann — Donald G. Watson
Wayne E. Hanson

[2] Federal Radiation Council, Report No. 7.

[3] Projected intake as used in this report is the accumulated intake of the radionuclide that would be received in the future by individuals in the population group from the contaminating event under the conditions cited.

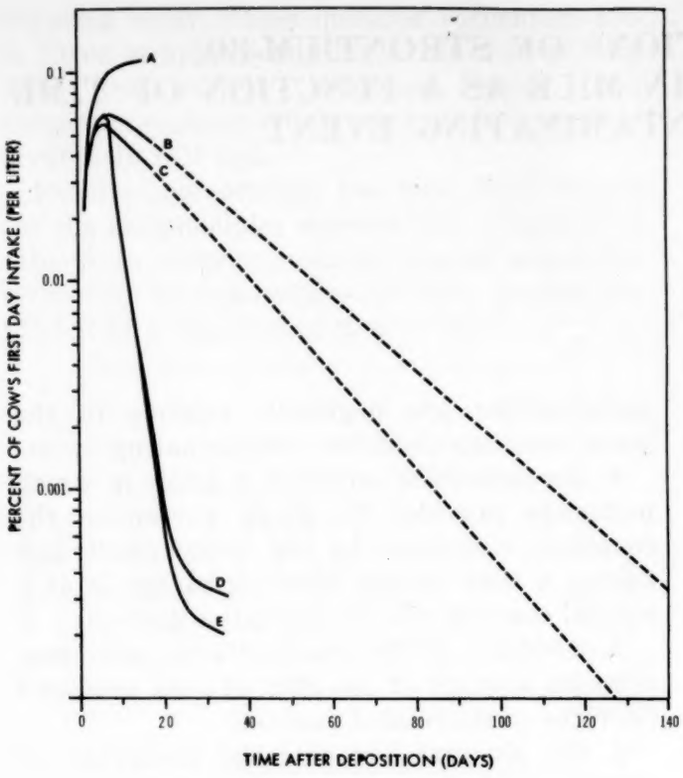


**Figure 1. Concentration of strontium–89 and strontium–90 in milk of cows**

cesium–137 into milk following the ingestion of these nuclides by cows as a function of time. These graphs are based upon the experimental data and equations developed in appendix 1. Curve A in figure 1 depicts the transfer of radiostrontium into milk based on experimental conditions in which cows ingest equal activities of radiostrontium daily. Curves B and C are computed to show the concentrations of strontium–90 and strontium–89, respectively, in milk following a single contaminating event on pasture assuming the cattle remain on the contaminated pasture. Curves D and E reflect the corresponding concentrations of strontium–90 and strontium–89 in milk following a single contaminating event assuming the cows are removed from the contaminated pasture at the time of maximum concentration of these nuclides in the milk (see Appendix 1 for derivation).

Curve A in figure 2 illustrates the appearance of radiocesium in milk of cows based on experimental results following daily equal ingested doses of cesium–137, Curve B is computed to show the concentration of cesium–137 in milk following a single contaminating event with the cows remaining on pasture, and Curve C shows the concentrations of cesium–137 following a single contaminating event if the cows are removed from pasture at time of maximum concentration of cesium–137 in the milk.

Those curves which relate to single contaminating events reflect a "disappearance half-time" from pasture of a little over two weeks for strontium–90 and cesium–137 and about thirteen days for strontium–89 (a few days shorter reflecting its shorter radioactive half-life).

Selected data from the Public Health Service Pasteurized Milk Network were also used to estimate the disappearance half-times of these nuclides under fallout conditions (appendix 2). Criteria were established to identify increased levels in milk contamination that probably resulted from single contamination events. These data suggest disappearance half-times of 11 to 13 days for strontium–89, 11 to 15 days for strontium–90 and 10 to 15 days for cesium–137.

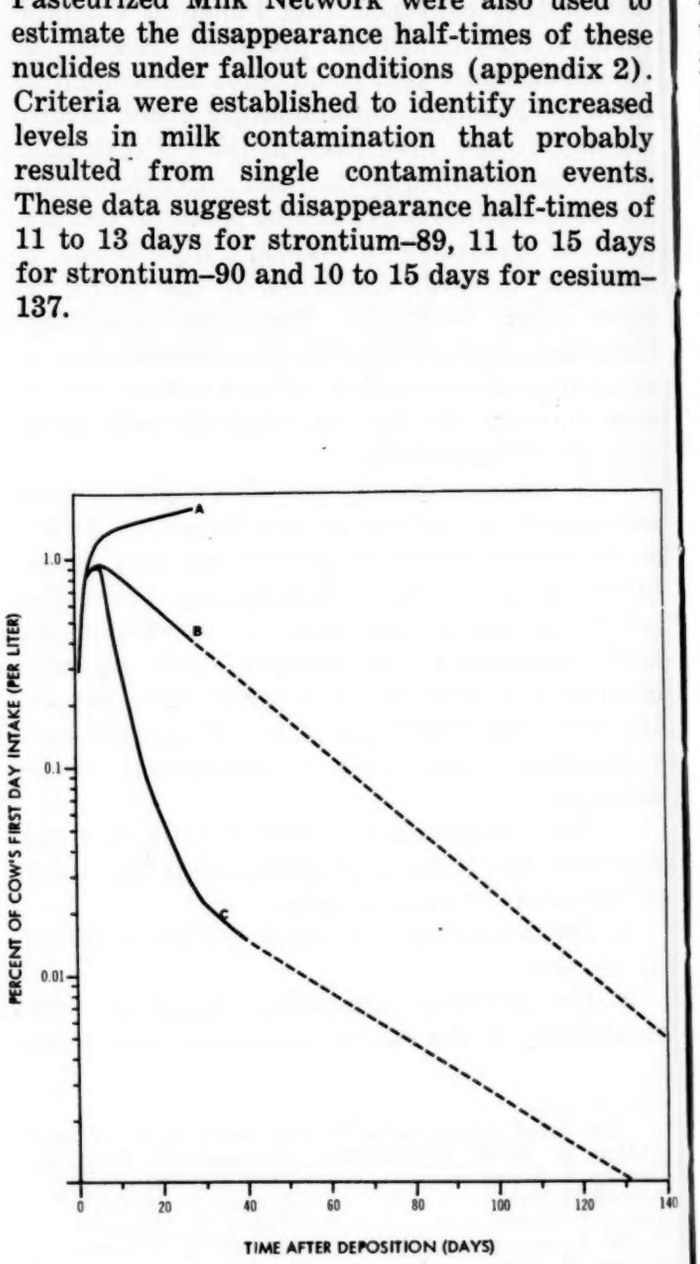


**Figure 2. Concentration of cesium–137 in milk of cows**

It is noted that the values for the disappearance half-times of these radionuclides from pasture are quite short relative to their physical half-lives. This is due to a combination of factors which diminish the contamination levels available to the grazing cow. The more important factors include removal from foliage by wind and rain and the normal cycle of plant growth combined with the grazing practices of dairy cattle. Based upon these half-times and assuming that the cattle remain on the contaminated pasture, the milk levels of the radionuclides of interest can be expected to decline to less than 1–2 percent of their maximum levels within a period of 3–4 months following the acute contaminating event. Therefore, it is suggested that the 100-day period following that contaminating event represents a reasonable approximation of the period of "total" projected intake.

The computations from appendix 1 are summarized in the tables that follow. In the tabular presentations $T_o$ represents the time at which the contaminating event occurs and $T_m$ the time required, in days, after the contaminating event for the maximum concentration of each nuclide to be reached in milk. Table 1 summarizes $T_m$ for each nuclide.

**Table 1. Time after deposition for maximum milk levels to occur**

| Nuclide | Tm |
|---|---|
| Strontium-89 | 7 days |
| Strontium-90 | 7 days |
| Cesium-137 | 6 days |

Table 2 presents the total projected cumulative intake as a ratio or multiple of the maximum concentration. For example, if the maximum concentration of strontium–89 were 1 $\mu$Ci/liter of milk and an individual consumes 1-liter of milk per day from the affected area for about 100 days, his total projected intake of strontium–89 would be about 27 $\mu$Ci. These ratios may be useful in predicting the magnitude of a contamination problem once the maximum concentration has been determined.

**Table 2. Ratios of total human projected intake to human intake at time of maximum concentration in milk**

| Nuclide | Ratio |
|---|---|
| Strontium-89 | 27 times the maximum value |
| Strontium-90 | 33 times the maximum value |
| Cesium-137 | 32 times the maximum value |

As previously indicated, if the cows remain on the contaminated pasture for about 100 days subsequent to the contaminating event, almost the total projected intake will have ensued. The actual periods calculated for the maximum milk concentration of each nuclide to be reduced by factors of 10 and 100 under conditions of continuous grazing on contaminated pasture are presented in table 3.

**Table 3. Time required for milk concentrations to be reduced by factors of 10 and 100 if cows remain on contaminated pasture**

| Nuclide | Time for reduction factor of: | |
|---|---|---|
| | *10* | *100* |
| Strontium-89 | 52 days | 94 days |
| Strontium-90 | 67 days | 124 days |
| Cesium-137 | 67 days | 125 days |

Table 4 lists the time periods required for the milk concentration to be reduced by factors of 10 and 100 after the cows are shifted to uncontaminated feed. The time periods for reduction are appreciably shorter as compared to the corresponding estimates in table 3 indicating the effectiveness of the protective action afforded by shifting the cows off the contaminated feed.

**Table 4. The time required for milk concentrations to be reduced by factors of 10 and 100 after cows are shifted to uncontaminated feed**

| Nuclide | Time for reduction factor of: | |
|---|---|---|
| | *10* | *100* |
| Strontium-89 | 6 days | 13 days |
| Strontium-90 | 6 days | 14 days |
| Cesium-137 | 8 days | 49 days |

**Table 5. The projected total intake avoided by shifting cattle to uncontaminated feed as related to the time the action is taken**

| Percent of projected total intake avoided | Approximate time after $T_0$ for shift to be made | | |
|---|---|---|---|
| | $^{89}Sr$ | $^{90}Sr$ | $^{137}Cs$ |
| | (days) | (days) | (days) |
| 50 | 13 | 17 | 14 |
| 75 | 6 | 7 | 5 |
| 90 | 2 | 2 | 2 |
| 99 | <1 | <1 | <1 |

Table 5 summarizes the effectiveness of the protective action of shifting cows to uncontaminated feed as a function of the time interval between the contaminating event ($T_o$) and the time that the action is instituted. These estimates show that in order for this protective action to effect at least a 50 percent reduction of projected intake, it must be instituted very soon (within a matter of days) after the contaminating event.

The calculations summarized in table 5 assume that individuals in the population are consuming the milk produced in the affected area as their exclusive milk supply before and after the "shift." An even more effective protective action, but one probably having more adverse impact on dairy marketing, would be to ban entirely for human consumption the milk from the affected area. This action also must be instituted early if its effectiveness is to be optimal; 10 to 20 percent of the total projected intake will have found its way into the milk produced in the contaminated area within 4–6 days after $T_o$.

The approximate nature of the preceding data and estimates must be emphasized. They primarily reflect the mechanism of transfer of these nuclides from pasture to milk following deposition of the radionuclides under the previously specified assumptions. The estimates do *not* pertain to the more persistent contamination problems resulting from residual contamination of soil, root mats or stem bases, or of crops other than pasture nor do they pertain to unusual conditions of vegetative growth. The patterns of milk contamination may be different if environmental conditions quite unlike those assumed should prevail.

The Panel also considered the exposure potential of food other than fresh milk (appendices 3 and 4) and concluded that if a contaminating event involves a milkshed, particularly one in which dairy cows are on pasture, milk will probably be the major and limiting mode of transmission for all three nuclides and generally the concentrations found in milk should provide valid bases for considering control measures in other foods as well as milk. Because the nuclides of interest have relatively long physical half-lives, their contamination potential via foods other than milk cannot be ignored. Foods other than fresh milk may be additionally important pathways of human exposure or, with little or no contamination of pasture involved, the most significant pathways of human exposure. The agricultural, geographical and radiobiological variables are too numerous and complex to allow any quantitative estimates or predictions of the relative importance of foods other than fresh milk in terms of their projected intakes. However, the marketing practices for most foods, as compared to fresh milk, are such that considerably more time will be available to assess any contamination problems and to implement any control procedures that may be warranted.

## Appendix 1. Radionuclide concentrations in milk following a contaminating event involving pasture

*J. J. Davis, F. W. Lengemann, and G. F. Fries*

The purpose of this paper is to develop the equations which describe the concentration of strontium–89, strontium–90 and cesium–137 in milk from cows grazing a pasture that has been contaminated by an acute event. After developing the basic equations, it is possible to derive a number of estimates describing the radionuclide intake by people consuming milk from these cows.

The assumptions concerning the contaminating event were:

1. The deposition time is short (hours to days);
2. The chemical and physical properties are the same as found in worldwide fallout;
3. The deposition is on pasture supplying feed for dairy cows;
4. Background and cumulative soil levels are negligible; and
5. Human consumption of milk is one liter per day.

There are three factors that affect the radionuclide concentration in milk following a single contaminating event. These are: the rate of nuclide secretion into milk as a result of the initiation of continuous nuclide intake by the cow; the decreasing rate of nuclide intake by the cow due to pasture "losses"; and the decreasing rate of radionuclide intake by the cow due to radioactive decay.

In general, data from environmental survey studies were not appropriate for the purposes of this paper because most of the depositions that have occurred as a result of nuclear testing were of a long duration and can not be considered single events. For this reason the equations describing the milk concentrations of radionuclides were derived from laboratory tracer studies. When possible, data from environmental studies were examined to be certain that there were no important disagreements with the tracer studies.

The rate of radiostrontium transfer to milk under conditions of continuous intake was estimated from the average of 5 cows which were given twice-daily doses of strontium–85 for a period of about 15 days (*1*). One cow received the isotope for a period of 65 days and it was found that a complete equilibrium is not established within this period. By graphic analysis it was found that the basic curve (A of figure 1) for radiostrontium transfer to milk could be described by the equation:*

$$(1) \qquad A = 0.1e^{0.008t}(1 - e^{-0.26t})$$

Similarly, the rate of radiocesium transfer to milk under conditions of continuous intake was estimated from the average of 7 cows which were given twice-daily doses of cesium–137 for a period of 35 days (*1, 2*). Graphic analysis of the basic equation for the appearance of radiocesium in cows' milk (curve A of figure 2) gave the equation:

$$(2) \qquad A = 1.3e^{0.01t}(1 - e^{-0.41t})$$

Neither of the basic equations reflect the decreasing nuclide intake by cows which would occur as a result of "vegetative losses" and radioactive decay. "Vegetative losses" includes all processes which affect the concentration of the nuclides per unit dry matter of pasture. This includes such factors as weathering, dilution by new growth, and removal of the nuclides by the cow's consumption.

Data of Milburn and Taylor (*3*) indicate that the half-time of radiostrontium on pasture grass was about 14 days. Data of Ward (*4*) for iodine–131 and cesium–137 content of the milk of a group of cows show that the iodine is lost from pasture grasses with a half-time of 17.6 days, while cesium showed a rate of loss

* In all equations in this paper, A is the radionuclide concentration of milk in percent of intake by the cow on the first day per liter of milk and t is time in days after deposition.

with a half-time of about 13 days. Therefore, it seemed reasonable to use the value of 14 days as an estimate of the time for the concentration of radioisotopes on pasture grass to decrease to one-half of the initial value. To account for this factor it is necessary to multiply the basic equations by $e^{-0.05t}$. Because of the long radioactive half-lives of strontium–90 and cesium–137, the decrease in intake of these nuclides by the cow over the period of interest will be insignificant.

The equation expressing strontium–90 content of milk of cows on contaminated pasture following a single deposition then becomes:

$$(3) \qquad A = 0.1e^{0.008t}(1-e^{-0.26t})(e^{-0.05t})$$

This equation is plotted as curve B of figure 1. The broken line indicates extension of the calculation beyond the limits of the experimental curve.

Equation (3) is also applicable to strontium–89 if a further correction is made for the short physical half-life (50.5 days) of this radionuclide. Its equation becomes:

$$(4) \qquad A = 0.1e^{0.008t}(1-e^{-0.26t})(e^{-0.05t})(e^{-0.014t})$$

This equation has been plotted as curve C of figure 1.

When pasture losses of cesium are added, equation (2) modifies to:

$$(5) \qquad A = 1.3e^{0.01t}(1-e^{-0.41t})(e^{-0.05t})$$

This equation is plotted as curve B in figure 2.

Another parameter important for the purposes of this paper is the rate of decrease of the radionuclide concentrations of milk if the cows are removed from the contaminated pastures to an uncontaminated feed source. There is no information available that is directly applicable to this situation. However, the declining phases of single dose tracer experiments should be fairly comparable and data from this source have been used.

Milk concentration curves for 30 cows given a single dose of radiostrontium were averaged (*1, 5, 6, 7*). Such a curve takes about 24 to 48 hours to reach a peak and then declines as an exponential function. The equation for the decline is:

$$(6) \qquad {}^{90}\text{Sr (percent dose/liter)} = 0.054e^{-0.37t} + 0.000375e^{-0.01t}$$

The equation for strontium–89 would be similar except that a factor must be included for radioactive decay. The equation for strontium–89 then becomes:

$$(7) \qquad {}^{89}\text{Sr (percent dose/liter)} = (0.054e^{-0.37t} + 0.000375e^{-0.01t})(e^{-0.014t})$$

These equations have been plotted in figure 1 as curves D and E and represent milk concentrations of strontium–90 and strontium–89, respectively.

Milk concentration curves of 11 cows given a single dose of radiocesium were averaged. The data represented cows followed for a period of from 9 to 30 days (*1, 7, 8, 9*). The equation for the declining phase of the curve was:

$$(8) \qquad {}^{137}\text{Cs (percent dose/liter)} = 0.234e^{-0.37t} + 0.081e^{-0.17t} + 0.011e^{-0.02t}$$

The equations describing the milk concentration of the various radionuclides—Nos. (3), (4), (5)—show that for cows on a pasture contaminated over a relatively short length of time, the concentration of cesium–137 in milk will reach a peak at about 6 days. For both strontium isotopes the peak will occur at about 7 days. After reaching a peak, the radionuclide concentrations begin a decline which has a half-time of about 14 days. The nuclide concentration of milk at the time of the maximum will be 0.94, 0.064 and 0.057 percent of the cow's intake on the first day for cesium–137, strontium–90, and strontium–89, respectively.

In developing the equations, it was necessary to express the concentration of radionuclides in milk as a function of the cow's intake of radionuclides. In practice, the cow's intake on pasture cannot be measured. However, the relationships between measured concentrations of radionuclides in milk and the projected intakes by man are valid regardless of the units used.

The projected radionuclide intake of a person drinking one liter of milk per day from cows kept on contaminated pasture can be calculated by integrating equations Nos. (3), (4) and (5) from $t = 0$ to $t = \infty$. For strontium–89, strontium–90, and cesium–137, the projected radionuclide intake by man will be 1.55, 2.11,

and 30 percent of the cows' intake on the first day, respectively. If these values are divided by the corresponding maximum values of radionuclide concentration in milk, the projected intake by man (from $t = 0$ to $t = \infty$) would be 27, 33, and 32 times the maximum concentrations in milk, respectively.

The percentage of the total projected intake by a person that will occur by the time of maximum concentration of radionuclides in milk can be estimated by integrating these equations between $t = 0$ and $t = 6$ days for cesium–137 and $t = 0$ and $t = 7$ days for strontium–89 and strontium–90. It was estimated that 16, 21, and 16 percent of the total projected radionuclide intake by a person for cesium–137, strontium–89, and strontium–90, respectively, will occur by the time the milk values are maximized.

If the cows are maintained on pasture, the equations (3), (4), and (5) can be used to calculate the time for the radionuclide concentration in milk to be reduced by a factor of 10 and 100 due to pasture losses and radioactive decay. For simplified calculating, it was assumed that the value $(1-e^{-kt})$ had approached close enough to 1 to be disregarded. The results are shown in table 6.

**Table 6. Time required to reduce the radionuclide concentration of milk when the cows are not removed from pasture**

| Nuclide | Reduction factor, days | |
|---|---|---|
| | for 10-fold reduction | for 100-fold reduction |
| Strontium-89 | 52 | 94 |
| Strontium-90 | 67 | 124 |
| Cesium-137 | 67 | 125 |

In order to predict what would occur if cows are changed to uncontaminated feed, it is necessary to evaluate equations (6), (7), and (8). The time required to reduce the radionuclide concentration in milk by factors of 10 and 100 is shown in table 7. These values were obtained by graphical analysis.

**Table 7. Time required to reduce the radionuclide concentration of milk after the cows are removed from pasture**

| Nuclide | Reduction factor, days | |
|---|---|---|
| | for 10-fold reduction | for 100-fold reduction |
| Strontium-89 | 6 | 13 |
| Strontium-90 | 6 | 14 |
| Cesium-137 | 8 | 49 |

If the equations (6), (7), and (8) are integrated from 0 to $\infty$, the projected radionuclide intake by man (at one liter of milk/day) will equal 2.86, 3.36, and 5.1 times the concentration in milk at the time of the shift to uncontaminated feed for strontium–89, strontium–90, and cesium–137, respectively. The use of these values, together with the corresponding maximum concentration values in milk and the projected intake up to the time of maximum concentration, make it possible to estimate the projected intake that would occur if the cows were shifted to uncontaminated feed at the time of maximum concentration. For strontium–89 this value will be approximately 32 percent of the total projected intake when the cows are not shifted from the contaminated pasture. Similar values for strontium–90 and cesium–137 are 26 percent and 31 percent.

By similar types of calculations, it is possible to estimate the time that cows must be shifted to uncontaminated feed in order to avoid various percentages of the projected intakes. A summary of these values is presented in table 8.

**Table 8. Approximate time after deposition for a shift to be made in order to avoid specified percentages of the total projected intake by man**

| Projected intake avoided | Cesium-137 | Strontium-89 | Strontium-90 |
|---|---|---|---|
| (%) | (days) | (days) | (days) |
| 50 | 14 | 13 | 17 |
| 75 | 5 | 6 | 7 |
| 90 | 2 | 2 | 2 |

**Appendix 2. Preliminary estimates of disappearance half-times for strontium–90 and cesium–137 based on 1962 weekly data from the Pasteurized Milk Network[1] (Averages for the U.S. were based on 4 sets of criteria used to identify an acute contaminating event during the pasture season at each of the milk stations in the 48 conterminous States.)**

| Criteria | Disappearance half-times (average in days)[2] | Number of curves identified |
|---|---|---|
| Set 1 | | |
| Strontium-90 | 13 | 16 |
| Strontium-90 | 15 | 16 |
| Cesium-137 | 15 | 16 |
| Set 2 | | |
| Strontium-89 | 11 | 39 |
| Set 3 | | |
| Strontium-90 | 11 | 50 |
| Set 4 | | |
| Cesium-137 | 10 | 25 |

[1] Disappearance half-times of selected radionuclides in milk based on Surveillance Data, Gaynell Jayson and Anne G. Berger, DHEW, Public Health Service, Division of Radiological Health (report in preparation).

[2] An effective half-life or a disappearance half-time was determined for a given episode following the date of the maximum observed concentration.

*Criteria*

Set 1

A. Concomitant increases in $^{89}Sr$, $^{90}Sr$ and $^{137}Cs$

B. A 100 percent or greater increase in one or more of the nuclides in a one or two-week period

C. Maximum or peak concentrations of all three nuclides within a two-week period

D. Cows on pasture for the period

Set 2

A. 200 percent or greater increase in $^{89}Sr$ in a one or two-week period

B. Cows on pasture for the period

Set 3

A. 100 percent increase or greater in $^{90}Sr$ in a one or two-week period

B. Cows on pasture for the period

Set 4

A. 200 percent or greater increase in $^{137}Cs$ in a one or two-week period

B. Cows on pasture for the period

## Appendix 3. The relative magnitude of milk and non-milk contributions to strontium–90 and cesium–137 body burdens

*F. P. Hungate*

In the United States the general population dietary pattern is such that milk is the major route by which strontium–90 is taken into man. From dietary studies of New York, Chicago, and San Francisco (as reported in HASL–144) the average ratio of strontium-units (pCi $^{90}Sr$ / gCa) from total diet to those from milk ranged from 1 to 2.5. In terms of strontium–90 in total diet to that in milk, this ratio varies from 1.5 in New York to 3 in San Francisco. For cesium–137 the ratios of total diet to milk ranges from about 2 in New York to nearly 8 in San Francisco. The HASL report tentatively concludes that, while milk appears to define the average strontium–90 intake, other products such as meat and cereals may assume equal or greater importance than milk with respect to body burdens of cesium–137.

These Tri-City diet data are from large groups of people and, as such, it is surprising that they show the variation they do. Individual dietary patterns involving the intake of large amounts of other foods containing higher than average concentrations of fallout radionuclides would inevitably lead to strontium–90 intakes which are primarily dependent on non-dairy products. In the case of strontium–90 this individual variation is largely outweighed by the importance of milk in the diet of infants and children. This same importance does not appear to hold for cesium–137.

Since action levels will undoubtedly have to be applied with respect to small and local segments of the general population, exceptional rather than average dietary patterns should be considered for their potential buildup of non-

average body burdens. To date, relatively few of such unusual dietary patterns have been shown to produce unusual body burdens of radionuclides. This failure to identify any unusual patterns is undoubtedly the consequence of a lack of extensive studies of individual diets under conditions where body burdens can be evaluated through whole-body counting.

The study of cesium–137 body burdens in Alaskan Eskimos and Laplanders and associated evaluation of dietary patterns has been done on an individual basis. In these groups, cesium–137 body burdens are nearly 100 times those of individuals from the conterminous States having a "normal" intake of cesium–137 via milk. This high body burden in Eskimos occurs in spite of the fact that fallout levels in Alaska are well below those in areas less far north. With the exception of small children, the Eskimos consume essentially no milk or milk products but instead take in the vast majority of their cesium–137 by way of caribou meat.

Similar kinds of deviations from "normal" nutritional patterns may occur through food chains little suspected as of the present time. One such has been recently identified in Finnish studies in which fish were shown to contain up to 20 pCi $^{137}Cs/g$. Since fish are a major item in some people's diet, significantly higher than average body burdens can be expected.

Any concept of radionuclide burdens as derived through milk are automatically not valid for substantial parts of the world in which milk consumption is near zero for any except infants.

## Appendix 4. Intake of radiocesium from contaminated meat

*F. W. Lengemann*

Milk and meat can constitute important pathways for the dissemination of radiocesium to the human population. The basic equations for secretion of cesium–137 into milk have been presented along with the equations for strontium–89 and strontium–90 levels in milk (Appendix 1). This section will present the same type of analysis for meat as a source of radiocesium for humans.

As in the previous section on milk the basic assumption was a single contaminating event that takes place in a short interval of time. It is assumed that cattle were grazing the pastures at the time of the event. Unlike milk, it must be further assumed that animals are taken directly from pasture and processed into meat and meat products. The number of animals must necessarily be large and the food distribution channels of sufficient magnitude so that a single animal contributes at most only one portion of the daily meat intake of an individual human. Such things as freezer storage of large amounts of meat from a single animal for a single family necessarily invalidate the analysis developed here.

The data presented here are body contents of cesium from 4 of the 7 cows used for the milk analysis (Appendix 1) and were given radiocesium daily for a period of 30 days. While the cows were milking animals, it is not anticipated that the general shape of the curve should be much different for beef animals since only about 10 percent of the daily intake of radiocesium is secreted into the milk.

The basic equation for meat radiocesium content from these experiments is:

(1) percent of daily cesium intake/kg meat
$$= 0.84e^{0.0073t}(1-e^{-0.2t})$$

For uniformity it is again assumed that the loss of cesium–137 from pasture grass is in the order of 14 days. The equation then modifies to:

(2) percent of daily cesium intake/kg meat
$$= 0.84e^{0.0073t}(1-e^{-0.2t})(e^{-0.05t})$$

The problem also entailed estimating what would happen to meat cesium–137 if the animals were removed from pasture. No data is available on this point; therefore the equation for the radiocesium content of milk after a single dose was used. The equation is:

(3) percent $^{137}Cs/kg = 0.23e^{-0.37t}$
$$+0.08e^{-0.17t}+0.01e^{-0.02t}$$

The use of this equation seemed reasonable since the cesium does not form organic combinations.

The equation (1) shows that when cattle are on a contaminated pasture the muscle concentration of cesium should peak at about 8 days. Integrating this equation from zero to infinity and dividing this value by the maximum concentration in meat (day 8) shows that the human intake of cesium–137 will be 34 times the maximum observed cesium concentration in meat. For this computation to hold, the animals must remain on pasture until slaughtered; the human must consume the flesh of a different animal each day, and must consume 1 kg of meat per day. If the meat consumption is only 0.5 kg then the total intake will be 17 times the maximum concentration. About 17 percent of the projected intake will take place in the first 8 days.

If the animals are maintained on pasture, the cesium–137 in the meat will decline due to pasture losses of the radioisotope. It is calculated that at day 68 the meat cesium–137 will be at a level 1æ10 that seen on day 8. On day 122 the cesium–137 will be 1/100 that of day 8.

These factors are in excellent agreement with those for milk (Appendix 1) and support the use of milk concentration curves for an index of muscle cesium levels. If at day 8, the time of maximum tissue cesium concentration, the animals are shifted to an uncontaminated feed, it can be calculated that it would take 8 and 49 days for the meat cesium–137 concentration to drop by a factor of 10 and 100, respectively. For individuals consuming meat from these animals it is calculated that their projected intake of cesium–137 will be 32 percent of that if the animals are not transferred from the contaminated pastures.

As for milk, a reduction of the projected intake by 50 percent can be accomplished by changing the animals to uncontaminated feed at about 20 days. A change at about 7 days will effect a 75 percent reduction; a change at 2 days, a 90 percent reduction; and at day 1, a 95 percent reduction.

It is customary to move dairy cattle directly from pasture to the slaughter house and so this analysis has relevance to the practical situation. The 24 million dairy cattle in this country constitute about half of the meat supply of this country. Most of these animals are processed into meat products such as chopped meat and bologna. For beef cattle the usual practice is to fatten the animals for several months on high grain diets before slaughter. Thus, these animals could be expected to be low in cesium–137 even in areas where a contaminating event has taken place.

REFERENCES


(*1*) WENTWORTH, R. A. Unpublished data.

(*2*) LENGEMANN, F. W. Unpublished data.

(*3*) MILBURN, G. M. and R. TAYLOR. Contamination of permanent pastures with strontium–90 and cesium–137. ARCRL Anal Rep 1962–1963, p. 73 (1963).

(*4*) WARD, G. Unpublished data.

(*5*) GARNER, R. J. and B. F. SANSON. Transfer of iodine–131 and strontium–89 from diet to milk in cattle. Veterinary Rec 71:670–673 (1959).

(*6*) CRAGLE, R. J. Strontium and calcium uptake and excretion in lactating dairy cows. J Dairy Sci 42:1367 (1959).

(*7*) LEBEDINSKY, A. W. U. N. Document A/AC 82 G/R. 50 (1956).

(*8*) HOOD, S. L. and C. L. COMAR. Metabolism of cesium–137 in laboratory and domestic animals. Oak Ridge Operations Office, ORO–91 (May 1953).

(*9*) CRAGLE, R. J. Uptake and excretion of Cs–137 and potassium–42 in lactating dairy cows. J Dairy Sci 44:352 (1961).

# Section III—Water

## GROSS RADIOACTIVITY AND STRONTIUM-90 IN SURFACE WATERS OF THE UNITED STATES, JANUARY 1965

*Division of Water Supply and Pollution Control, Public Health Service*

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has been expanded to 131 stations as of June 1, 1965. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining current and general levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–6*).

### *Sampling procedures*

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations for the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term radioactivity effects from current or recent nuclear tests or events.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the date of collection.

### *Analytical methods*

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for

counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of $U_3O_8$, which give a known count rate if the instrument is performing properly, are used for daily checking of the counter.

*Results*

Table 1 presents January 1965 results of alpha and beta analyses of U.S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first stations listed begin closest to the headwaters. These data are preliminary. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1, which gives the January 1965 average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Gross radioactivity results for 1957–1962 have been summarized by Weaver *et al* (*8*).

*Strontium–90 determinations and results, October-December 1964*

Beginning in 1959, strontium–90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except at those stations immediately below nuclear installations, where quarterly analyses were continued. The method used for

**Table 1. Radioactivity in raw surface waters, January 1965** [a]

| Station | Beta activity, pCi/liter | | | Alpha activity, pCi/liter | | |
|---|---|---|---|---|---|---|
| | Suspended | Dissolved | Total | Suspended | Dissolved | Total |
| Animas River: | | | | | | |
| Cedar Hill, N. Mex. | 6 | 14 | 20 | 2 | 2 | 4 |
| Arkansas River: | | | | | | |
| Coolidge, Kans. | 8 | 93 | 101 | 1 | 38 | 39 |
| Ponca City, Okla. | 0 | 17 | 17 | 0 | 4 | 4 |
| Atchafalaya River: | | | | | | |
| Morgan City, La[b] | 268 | 10 | 278 | 60 | 2 | 62 |
| Bear River: | | | | | | |
| Preston, Idaho | 0 | 12 | 12 | 0 | 3 | 3 |
| Big Horn River: | | | | | | |
| Hardin, Mont. | 7 | 26 | 33 | 2 | 10 | 12 |
| Clinch River: | | | | | | |
| Clinton, Tenn. | 1 | 7 | 8 | 0 | 0 | 0 |
| Kingston, Tenn. | 8 | 36 | 44 | <1 | 0 | <1 |
| Colorado River: | | | | | | |
| Loma, Colo. | 1 | 16 | 17 | 1 | 9 | 10 |
| Page, Ariz. | 3 | 31 | 34 | 0 | 10 | 10 |
| Parker Dam, Calif.-Ariz. | 1 | 28 | 29 | 0 | 10 | 10 |
| Columbia River: | | | | | | |
| Wenatchee, Wash. | 3 | 7 | 10 | 0 | 1 | 1 |
| Pasco, Wash. | 21 | 403 | 424 | 0 | 1 | 1 |
| Clatskanie, Ore. | 15 | 23 | 38 | 2 | 2 | 4 |
| Connecticut River: | | | | | | |
| Enfield Dam, Conn. | 20 | 9 | 29 | 0 | 1 | 1 |
| Coosa River: | | | | | | |
| Rome, Ga. | 5 | 6 | 11 | 1 | 0 | 1 |
| Cumberland River: | | | | | | |
| Cheatham Lock, Tenn. | 8 | 6 | 14 | 2 | 0 | 2 |
| Delaware River: | | | | | | |
| Philadelphia, Pa. | 29 | 6 | 35 | 6 | 0 | 6 |
| Great Lakes: | | | | | | |
| Duluth, Minn. | 6 | 12 | 18 | 0 | 0 | 0 |
| Hudson River: | | | | | | |
| Poughkeepsie, N.Y. | 8 | 14 | 22 | 1 | 0 | 1 |
| Kansas River: | | | | | | |
| De Soto, Kans. | 14 | 17 | 31 | 6 | 4 | 10 |
| Maumee River: | | | | | | |
| Toledo, Ohio | 4 | 20 | 24 | 1 | 1 | 2 |
| Mississippi River: | | | | | | |
| St. Paul, Minn. | 1 | 20 | 21 | 0 | 1 | 1 |
| E. St. Louis, Ill. | 15 | 19 | 34 | 5 | 1 | 6 |
| New Orleans, La. | 36 | 12 | 48 | 3 | 1 | 4 |
| New Roads, La. | 17 | 12 | 29 | 5 | 1 | 6 |
| Missouri River: | | | | | | |
| Williston, N. Dak. | 29 | 26 | 55 | 7 | 6 | 13 |
| St. Joseph, Mo. | 6 | 25 | 31 | 1 | 3 | 4 |
| North Platte River: | | | | | | |
| Henry, Nebr. | 3 | 47 | 50 | 0 | 30 | 30 |
| Ohio River: | | | | | | |
| Cairo, Ill. | 25 | 5 | 30 | 4 | 0 | 4 |
| Toronto, Ohio | 4 | 11 | 15 | 0 | 0 | 0 |
| Platte River: | | | | | | |
| Plattsmouth, Nebr. | 5 | 21 | 26 | 2 | 6 | 8 |
| Potomac River: | | | | | | |
| Washington, D.C. | 18 | 5 | 23 | 3 | 0 | 3 |
| Red River, North: | | | | | | |
| Grand Forks, N. Dak. | 2 | 28 | 30 | 0 | 0 | 0 |
| Red River, South: | | | | | | |
| Alexandria, La. | 18 | 21 | 39 | 3 | 2 | 5 |
| Rio Grande: | | | | | | |
| El Paso, Tex. | 8 | 34 | 42 | 2 | 9 | 11 |
| Laredo, Tex. | 14 | 38 | 52 | 1 | 4 | 5 |
| San Joaquin River: | | | | | | |
| Vernalis, Calif. | 3 | 0 | 3 | 1 | 1 | 2 |
| San Juan River: | | | | | | |
| Shiprock, N. Mex. | 41 | 12 | 53 | 16 | 3 | 19 |
| Savannah River: | | | | | | |
| Port Wentworth, Ga. | 2 | 9 | 11 | 0 | 1 | 1 |
| Snake River: | | | | | | |
| Wawawai, Wash. | 5 | 9 | 14 | 1 | 2 | 3 |
| South Platte River: | | | | | | |
| Julesburg, Colo. | 14 | 61 | 75 | 3 | 37 | 40 |
| Tennessee River: | | | | | | |
| Chattanooga, Tenn. | 4 | 10 | 14 | 0 | 1 | 1 |
| Wabash River: | | | | | | |
| New Harmony, Ind. | 6 | 10 | 16 | 1 | 1 | 2 |
| Yellowstone River: | | | | | | |
| Sidney, Mont. | 2 | 20 | 22 | 0 | 5 | 5 |
| Maximum | 268 | 403 | 424 | 60 | 38 | 62 |
| Minimum | 0 | 0 | 3 | 0 | 0 | 0 |

[a] These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time this report becomes available. For final data, one should consult the system's annual report.

[b] The increased radioactivity observed at this station is being investigated further and will be discussed in a forthcoming issue of Radiological Health Data.


**Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, January 1965**

determining strontium–90 is a modification of a procedure described by Harley (*9*). The yttrium–90 together with an yttrium carrier is precipitated as yttrium oxalate and the latter is washed, dried, weighed, and counted in a low-background, anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium–90 concentrations in U.S. surface waters for October-December 1964. The stations are arranged in the table according to their relative locations on the river, the first station being closest to the headwaters. Floyd and Weaver summarized the strontium–90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*10*).

An improvement has been made in the determination of the counting efficiency of the low-background anticoincidence end-window counter for the counting of yttrium–90 in the strontium–90 determination. Previously, an efficiency of approximately 33 percent had been determined on each of the two counting chambers with the use of a standard consisting of strontium–90-yttrium–90 in equilibrium. Before counting the present set of samples, the efficiencies obtained were 40.2 percent and 38.3 percent in the two counting chambers, respectively, with the use of pure yttrium–90 oxalate. The effect of these recent values is to lower strontium–90 values about 15 percent. Present data are calculated with the use of these more applicable efficiency values.

Sixty-eight quarterly composite samples were analyzed for strontium–90. The average concentration of strontium–90 is 1.80 pCi/liter.[1] The median concentration of strontium–90 is 1.69 pCi/liter. Twenty-nine stations showed no appreciable change over the previous quarter from which results had been obtained. Thirty-five stations showed a decrease in strontium–90 levels. Only one station, Wenatchee, Washington on the Columbia River showed an increase to 2.2 pCi/liter. The highest strontium–90 result for this quarter is 5.4 pCi/liter at Grand Forks, North Dakota. This value is 1.6 pCi/liter less than the previous determination. While there are no standards for strontium–90 activity of total solids in surface waters, the Public Health Service Drinking Water Standards set the limit for strontium–90 concentrations in drinking water at 10 pCi/liter (*11*). This limit for public water supplies is greater than the highest level observed in surface waters during October-December 1964.

The radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*12*). The Public Health Service Drinking Water Standards state that in the

[1] All comparisons of present strontium–90 data to previous data presented herein have been made after appropriate corrections for changes in determining counting efficiency.

**Table 2. Quarterly average strontium-90 concentrations in surface waters, October–December 1964, concentrations in pCi/liter**

| Station | $^{90}Sr$ |
|---|---|
| Allegheny River: | |
| Pittsburgh, Pa | 1.7 |
| Arkansas River: | |
| Ponca City, Okla | 2.9 |
| Little Rock, Ark | 2.9 |
| Pendleton Ferry, Ark | 2.8 |
| Big Horn River: | |
| Hardin, Mont | 1.7 |
| Chattahoochee River: | |
| Atlanta, Ga | 1.6 |
| Columbus, Ga | 1.2 |
| Chena River: | |
| Fairbanks, Alaska | 0.1 |
| Clinch River: | |
| Kingston, Tenn | 3.0 |
| Colorado River: | |
| Loma, Colo | 0.9 |
| Boulder City, Nev | 1.7 |
| Yuma, Ariz | 1.2 |
| Columbia River: | |
| Wenatchee, Wash | 1.8 |
| Pasco, Wash | 2.2 |
| McNary Dam, Ore | 1.6 |
| Clatskanie, Ore | 1.0 |
| Connecticut River: | |
| Northfield, Mass | 1.3 |
| Delaware River: | |
| Martins Creek, Pa | 1.3 |
| Philadelphia, Pa | 1.2 |
| Escambia River: | |
| Century, Fla | 0.9 |
| Great Lakes: | |
| Duluth, Minn | 0.5 |
| Milwaukee, Wis | 0.8 |
| Port Huron, Mich | 1.2 |
| Buffalo, N. Y | 2.3 |
| Hudson River: | |
| Poughkeepsie, N. Y | 2.0 |
| Illinois River: | |
| Peoria, Ill | 1.6 |
| Kansas River: | |
| DeSoto, Kans | 3.3 |
| Klamath River: | |
| Keno, Ore | 1.5 |
| Maumee River: | |
| Toledo, Ohio | 2.1 |
| Mississippi River: | |
| Dubuque, Iowa | 2.9 |
| East St. Louis, Ill | 2.7 |
| West Memphis, Ark | 2.2 |
| Delta, La | 2.4 |
| New Roads, La | 2.1 |
| Missouri River: | |
| Williston, N. Dak | 2.1 |
| Yankton, S. Dak | 3.3 |
| St. Joseph, Mo | 3.0 |
| Missouri City, Mo | 3.6 |
| Monongahela River: | |
| Pittsburgh, Pa | 1.8 |
| North Platte River: | |
| Henry, Nebr | 0.5 |
| Ohio River: | |
| Toronto, Ohio | 2.0 |
| Huntington, W. Va | 1.4 |
| Louisville, Ky | 2.1 |
| Cairo, Ill | 2.1 |
| Pend Oreille River: | |
| Albeni Falls Dam, Idaho | 1.0 |
| Potomac River: | |
| Williamsport, Md | 0.8 |
| Rainy River: | |
| Baudette, Minn | 3.5 |
| International Falls, Minn | 3.2 |
| Red River, North: | |
| Grand Forks, N. Dak | 5.4 |
| Red River, South: | |
| Index, Ark | 3.4 |
| Alexandria, La | 2.7 |
| Rio Grande: | |
| Alamosa, Colo | 0.7 |
| Laredo, Tex | 1.7 |
| Roanoke River: | |
| John H. Kerr Resr/Dam, Va | 1.5 |
| San Joaquin River: | |
| Vernalis, Calif | 1.0 |
| San Juan River: | |
| Shiprock, N. Mex | 2.1 |
| Savannah River: | |
| Port Wentworth, Ga | 1.8 |
| Shenandoah River: | |
| Berryville, Va | 0.5 |
| Snake River: | |
| Wawawai, Wash | 0.6 |
| Payette, Idaho | 0.6 |
| South Platte River: | |
| Julesburg, Colo | 0.7 |
| Tennessee River: | |
| Lenoir City, Tenn | 1.2 |
| Chattanooga, Tenn | 1.3 |
| Bridgeport, Ala | 1.0 |
| Truckee River: | |
| Farad, Calif | 0.6 |
| Verdigris River: | |
| Nowata, Okla | 3.0 |
| Wabash River: | |
| New Harmony, Ind | 1.6 |
| Willamette River: | |
| Portland, Ore | 0.3 |

absence of strontium–90 and alpha emitters,[2] a water supply is acceptable when the gross beta concentration does not exceed 1,000 pCi/liter (*11*).

REFERENCES


(*1*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. National water quality network annual compilation of data. PHS Publication No. 663, 1958 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.[3]

(*4*) *Ibid.*, 1961 Edition.[3]

(*5*) *Ibid.*, 1962 Edition.[3]

(*6*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. Water pollution surveillance system, annual compilation of data. PHS Publication No. 663 (Revised) 1963 Ed., Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*7*) AMERICAN PUBLIC HEALTH ASSOCIATION; AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater. 11th Edition, New York (1960).

(*8*) WEAVER, L., A. W. HOADLEY, and S. BAKER. Radioactivity in surface waters of the United States, 1957–1962. Rad Health Data 4: 306-16 (June 1963).

(*9*) HARLEY, J. H., Radiochemical Determinations of Strontium–90, Health and Safety Laboratory Manual of Standard Procedures, August 1962 Revision, Radiochemistry and Environmental Studies Division, HASL, U.S. Atomic Energy Commission, New York Operations Office (1962).

(*10*) FLOYD, E. P., and L. WEAVER. Trends of Strontium–90 Levels in Surface Waters of United States, 1959–1963. Rad Health Data 5: 390–394 (August 1964).

(*11*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. Public Health Service Publication No. 956, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (March 1963), price 30 cents.

(*12*) STRAUB, C. P. Significance of radioactivity data. JAWWA 53:704 (June 1961).


[2] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha emitters and strontium–90, respectively.

[3] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

# Section IV—Other Data

## STRONTIUM-90 IN HUMAN BONE, OCTOBER 1964–MARCH 1965

*Division of Radiological Health*
*Public Health Service*

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium–90 in measurable amounts has been present in the global environment for only about ten years and major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown their bone strontium–90 content to be low and age-independent (*1*).

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post-mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally this amount is readily available from older children but it presents some difficulties from the standpoint of infants and children under five years of age.

Collection efforts are concentrated in five areas representing a broad range of environmental strontium–90 levels. These areas include metropolitan centers at Boston, Cincinnati, New Orleans, Los Angeles and Seattle.[1] Occasional specimens are also received from a few other areas.

Most specimens received to date have been vertebrae and ribs. Efforts to collect long bones for comparison to British data have not been successful.

### *Laboratory procedures*

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Division of Radiological Health, at Winchester, Massachusetts. The yttrium fraction is separated from the bone ash by extraction with 2-thenoyltrifluoroacetone (TTA). The strontium–90 content is then calculated (*2*, *3*) from the yttrium–90 activity. "Blind" duplicate analyses are performed on 10–20 percent of the samples. In addition, pools of animal bone ash and adult human bone ash are analyzed in replicate on a continuing basis.

### *Results*

The results of laboratory analyses for October 1964 through March 1965 are presented in table 1. The samples are grouped by States within each of six geographical regions as shown in figure 1. These regions represent an attempt to combine some elements of climatic and topographic homogeneity with the pattern of strontium–90 levels as reflected by the Public Health Service Pasteurized Milk Network.

The data are reported as picocuries of strontium–90 per gram of ash (the primary determination), per gram of calcium (for comparison with other data and for purposes of model development), and per gram of bone (as a rough indication of dose). Two-sigma counting errors are reported for the ash concentration. Following the pattern of earlier reports

[1] The U.S. Atomic Energy Commission has an active program for the collection of bone samples in New York, Chicago, and San Francisco (*1*).

## Table 1. Details of samples and results of analysis, October 1964–March 1965

| Region, state, and sample | Age at death | Sex | Date of death | Bone [a] | Original weight (g) | Ash weight (g) | pCi $^{90}Sr$/g of | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ash $\pm 2\sigma$ C.E. | Calcium | Bone |
| **Northeast** | | | | | | | | | |
| Connecticut | | | | | | | | | |
| I-16(0008) | 8 y 11 m 6 d | M | 5-5-64 | V | 193.8 | 22.0 | 1.46±.11 | 3.99 | .17 |
| **Massachusetts** | | | | | | | | | |
| I-2(0063) | 10 y 11 m 6 d | M | 1-7-64 | V | 88.5 | 7.1 | 1.51±.09 | 4.12 | .12 |
| I-2(0064) | 25 y 5 m 24 d | M | 1-7-64 | V | 100.1 | 15.0 | .87±.14 | 2.30 | .13 |
| I-2(0066) | 4 y 7 m 19 d | M | 1-10-64 | V | 131.4 | 12.5 | 1.54±.15 | 4.26 | .15 |
| I-2(0069) | 13 y 7 m | M | 1-22-64 | V | 208.5 | 20.9 | 1.08±.09 | 2.94 | .11 |
| I-2(0070) | 11 y 10 m 3 d | M | 1-23-64 | V | 191.0 | 17.7 | .77±.08 | 2.10 | .07 |
| I-2(0071) | 13 y 8 m 5 d | M | 1-23-64 | V | 229.8 | 21.9 | 1.12±.08 | 2.98 | .11 |
| I-2(0072) | 11 y 0 m 18 d | M | 1-30-64 | V | 131.0 | 13.3 | 1.03±.12 | 2.85 | .11 |
| I-2(0073) | 6 y 7 m 12 d | M | 1-31-64 | V | 138.6 | 17.1 | 1.80±.13 | 4.83 | .22 |
| I-2(0077) | 12 y 8 m 26 d | M | 2-16-64 | V | 127.9 | 11.1 | 1.45±.16 | 4.29 | .13 |
| I-2(0078) | 12 y 4 m 7 d | F | 2-16-64 | V | 90.0 | 9.0 | .92±.13 | 2.52 | .09 |
| I-2(0079) | 23 y 0 m 23 d | F | 2-21-64 | V | 151.0 | 20.8 | 1.46±.10 | 3.84 | .20 |
| I-2(0080) | 11 y | F | 3-1-64 | V | 146.7 | 15.4 | 1.40±.12 | 3.79 | .15 |
| I-2(0085) | 8 y 9 m 2 d | M | 3-11-64 | V | 105.4 | 8.9 | 2.45±.23 | 6.95 | .21 |
| I-2(0087) | 8 y | M | 3-16-64 | V | 115.2 | 10.0 | 1.59±.16 | 4.45 | .14 |
| I-2(0088) | 8 y 4 m 21 d | M | 3-20-64 | V | 111.7 | 11.0 | 1.81±.17 | 4.97 | .18 |
| I-2(0089) | 12 y 8 m 15 d | M | 3-21-64 | V | 96.8 | 6.5 | 1.75±.22 | 4.94 | .12 |
| I-2(0091) | 9 y 9 m 20 d | F | 3-25-64 | V | 195.6 | 19.4 | 1.48±.10 | 3.99 | .15 |
| I-2(0093) | 6 y 6 m | M | 4-3-64 | V | 128.3 | 11.8 | 1.39±.10 | 4.19 | .13 |
| I-2(0094) | 15 y 5 m 7 d | F | 4-5-64 | V | 241.0 | 24.9 | 1.06±.08 | 2.90 | .11 |
| I-2(0095)[b] | 25 y 7 m | F | 4-5-64 | V | 134.3 | 15.9 | .60±.07 | 1.59 | .07 |
| I-2(0097)[b] | 11 y 11 m 23 d | F | 4-10-64 | V | 139.2 | 16.5 | 1.30±.10 | 3.41 | .15 |
| I-2(0097)[b] | 11 y 11 m 23 d | F | 4-10-64 | V | 139.2 | 16.5 | 1.11±.09 | 2.94 | .13 |
| I-2(0099) | 4 y 4 m | F | 4-21-64 | V | 105.8 | 9.3 | 2.09±.18 | 5.68 | .18 |
| I-2(0100) | 6 y 9 m 29 d | M | 4-28-64 | V | 89.0 | 8.3 | 1.49±.18 | 4.20 | .14 |
| I-2(0101) | 15 y 11 m | F | 5-2-64 | V | 103.9 | 12.7 | 1.89±.16 | 5.14 | .23 |
| I-2(0104) | 4 y 7 m | M | 5-10-64 | V | 120.3 | 9.9 | 1.80±.19 | 4.89 | .15 |
| I-2(0105) | 7 y 5 m 3 d | F | 5-14-64 | V | 121.2 | 9.3 | 2.27±.19 | 6.41 | .17 |
| I-2(0107)[c] | 4 y 5 m | F | 5-22-64 | V | 128.1 | 11.1 | 2.60±.18 | 7.28 | .23 |
| I-2(0107)[c] | 4 y 5 m | F | 5-22-64 | V | 128.1 | 11.1 | 2.90±.21 | 8.10 | .25 |
| I-2(0111)[b] | 11 y 1 m | F | 5-27-64 | V | 115.8 | 13.9 | 1.39±.12 | 3.60 | .17 |
| I-2(0111)[b] | 11 y 1 m | F | 5-27-64 | V | 115.8 | 13.9 | .94±.11 | 2.51 | .11 |
| I-2(0119) | 4 y 8 m 24 d | F | 7-17-64 | V | 75.3 | 8.1 | 2.58±.23 | 7.04 | .28 |
| I-2(0141) | 13 y | F | 12-12-64 | V | 133.6 | 13.5 | 1.32±.12 | 3.57 | .13 |
| I-2(0142) | 10 y | M | 12-12-64 | V | 163.4 | 17.3 | 1.84±.12 | 5.17 | .20 |
| I-7(0005)[b] | 17 y | M | 11-30-64 | V | 103.35 | 17.1 | 1.55±.11 | 4.14 | .26 |
| I-7(0007) | 10 y | F | 12-17-64 | V | 100.1 | 9.2 | 1.85±.18 | 5.21 | .17 |
| I-8(0004) | 16 y 5 m 16 d | F | 1-5-65 | V | 143.5 | 16.9 | 1.23±.11 | 3.40 | .14 |
| I-8(0007) | 24 y | F | 2-2-64 | V | 109.6 | 12.7 | 1.10±.12 | 2.90 | .13 |
| I-8(0011)[b] | 21 y 8 m 1 d | M | 5-4-64 | V | 96.4 | 14.1 | 1.31±.18 | 3.54 | .19 |
| I-8(0011)[b] | 21 y 8 m 1 d | M | 5-4-64 | V | 96.4 | 14.1 | 1.29±.11 | 3.42 | .19 |
| I-8(0012) | 22 y 17 d | F | 5-11-64 | V | 73.7 | 10.2 | 1.47±.25 | 3.88 | .20 |
| I-8(0014) | 17 y 5 m | M | 5-11-64 | V | 78.8 | 9.2 | 1.98±.29 | 5.39 | .23 |
| I-8(0015) | 20 y | M | 5-12-64 | V | 97.1 | 12.2 | 1.19±.18 | 3.12 | .15 |
| I-8(0018) | 6 y | M | 5-28-64 | V | 110.0 | 10.9 | 1.39±.14 | 3.78 | .14 |
| I-8(0019) | 10 y | F | 5-26-64 | V | 70.8 | 8.0 | 1.58±.18 | 4.12 | .18 |
| I-8(0021) | 17 y | F | 7-14-64 | V | 46.0 | 5.6 | 1.49±.29 | 3.94 | .18 |
| I-8(0022) | 6 y 10 m 25 d | F | 8-7-64 | V | 88.7 | 8.1 | 1.91±.20 | 5.53 | .17 |
| I-8(0023) | 20 y | M | 8-30-64 | V | 127.1 | 16.3 | 1.48±.13 | 3.98 | .19 |
| I-8(0024) | 2 y 6 m | F | 10-1-64 | V | 47.3 | 4.7 | 2.96±.92 | 8.35 | .29 |
| I-8(0025) | 22 y | M | 10-17-64 | V | 97.8 | 14.1 | 1.27±.12 | 3.38 | .18 |
| **New Jersey** | | | | | | | | | |
| II-36(0004) | 4 y 6 m 22 d | F | 4-20-64 | V, R | 203.1 | 9.6 | 1.57±.15 | 4.49 | .05 |
| **New York** | | | | | | | | | |
| II-10(0010)[b] | 14 y 1 m 26 d | M | 6-13-63 | V | 176.5 | 8.6 | .64±.13 | 1.84 | .02 |
| II-10(0018) | 12 y 1 m 4 d | F | 8-13-63 | V | 161.5 | 21.3 | .99±.09 | 2.66 | .13 |
| II-10(0025) | 11 y 2 m 15 d | M | 3-11-64 | V | 197.2 | 18.1 | 1.10±.10 | 3.06 | .10 |
| II-12(0011) | 15 y 1 m 19 d | F | 5-15-63 | V | 144.9 | 16.3 | .72±.08 | 1.91 | .08 |
| II-12(0012) | 13 y 7 m 8 d | M | 5-7-63 | V | 174.2 | 16.3 | .84±.10 | 2.33 | .08 |
| II-12(0014) | 24 y 4 m 25 d | M | 7-22-63 | V | 105.0 | 12.8 | 1.51±.13 | 3.98 | .18 |
| II-23(0001) | 21 y 4 m 5 d | M | 3-27-64 | V | 157.1 | 24.8 | 0.71±.07 | 1.85 | .11 |
| II-23(0004)[b] | 23 y 29 d | M | 6-23-64 | V | 135.2 | 16.7 | .89±.09 | 2.43 | .12 |
| II-23(0004)[b] | 23 y 29 d | M | 6-23-64 | V | 135.2 | 16.7 | .82±.08 | 2.10 | .10 |
| II-26(0002)[b] | 16 y 9 m 12 d | M | 6-6-63 | R | 48.3 | 15.9 | .99±.09 | 2.45 | .33 |
| II-26(0002)[b] | 16 y 9 m 12 d | M | 6-6-63 | R | 96.6 | 15.9 | .74±.09 | 1.85 | .12 |
| II-26(0003) | 16 y 14 d | M | 4-1-64 | R | 111.7 | 27.2 | 1.01±.07 | 2.58 | .27 |
| II-38(0010) | 9 y 1 m 13 d | M | 3-11-64 | V | 143.7 | 12.8 | 1.59±.15 | 4.38 | .14 |
| II-38(0011) | 11 y 2 m 23 d | M | 3-27-64 | V | 203.7 | 19.3 | 1.08±.09 | 3.00 | .10 |
| II-38(0012) | 24 y 11 m 4 d | F | 3-28-64 | V | 146.9 | 15.8 | .94±.10 | 2.52 | .10 |
| II-38(0021)[b] | 20 y 2 m 16 d | F | 5-18-64 | V | 116.6 | 18.3 | .53±.06 | 1.54 | .08 |
| II-38(0023) | 22 y 9 m 5 d | M | 5-19-64 | V | 239.5 | 23.3 | .65±.06 | 1.69 | .06 |
| **Pennsylvania** | | | | | | | | | |
| II-3(0006) | 23 y 2 m 15 d | M | 8-23-63 | V | 152.2 | 20.9 | .83±.09 | 2.17 | .11 |
| II-3(0007) | 19 y 4 m 22 d | F | 11-25-63 | V | 195.5 | 29.8 | .91±.06 | 2.43 | .14 |
| II-3(0009) | 13 y 3 m 29 d | M | 4-18-64 | V | 161.7 | 15.3 | 1.49±.13 | 4.16 | .14 |
| II-4(0022) | 24 y 1 d | F | 2-25-64 | V | 226.8 | 22.1 | 1.22±.09 | 3.23 | .06 |
| II-19(0035) | 19 y 9 m | M | 5-20-63 | V | 143.4 | 21.0 | .65±.07 | 1.67 | .10 |
| II-19(0036) | 22 y 1 m 15 d | M | 5-17-63 | V | 167.3 | 24.3 | .57±.06 | 1.51 | .09 |

**Table 1. Details of samples and results of analysis, October 1964–March 1965—Continued**

| Region, state, and sample | Age at death | Sex | Date of death | Bone [a] | Original weight (g) | Ash weight (g) | pCi $^{90}Sr$/g of | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ash ±2σ C.E. | Calcium | Bone |
| Northeast—Continued | | | | | | | | | |
| Pennsylvania | | | | | | | | | |
| II-19(0037) | 15 y 2 m 11 d | M | 6-17-63 | V | 195.7 | 22.0 | .94±.08 | 2.50 | .11 |
| II-19(0051) | 8 y 8 m 6 d | M | 10-21-63 | V | 90.0 | 9.8 | 1.51±.19 | 4.14 | .16 |
| II-19(0055) | 23 y 11 m 24 d | F | 11-6-63 | V | 182.7 | 21.7 | .88±.08 | 2.38 | .11 |
| II-19(0057)[b] | 21 y | F | 11-30-63 | V | 111.3 | 18.4 | .85±.09 | 2.23 | .07 |
| II-19(0057)[b] | 21 y | F | 11-30-63 | V | 111.3 | 18.4 | .78±.08 | 2.03 | .13 |
| II-19(0062) | 6 y 7 m 21 d | F | 4-1-64 | V | 154.5 | 17.3 | 1.33±.11 | 3.64 | .15 |
| Vermont | | | | | | | | | |
| I-6(0033) | 19 y 9 m 20 d | M | 1-9-64 | V | 174.3 | 21.1 | 1.33±.09 | 3.55 | .16 |
| I-6(0035)[b] | 23 y 8 m 5 d | M | 2-8-64 | V | 139.4 | 17.1 | 1.15±.09 | 3.09 | .14 |
| I-6(0035)[b] | 23 y 8 m 5 d | M | 2-8-64 | V | 139.4 | 17.1 | 1.35±.11 | 3.63 | .17 |
| I-6(0037) | 15 y 8 m 9 d | M | 4-3-64 | V | 169.8 | 23.9 | 1.59±.09 | 4.31 | .23 |
| I-6(0038) | 15 y 1 m 2 d | M | 4-3-64 | V | 186.8 | 22.9 | 1.44±.09 | 3.99 | .18 |
| I-6(0039) | 14 y 21 d | M | 4-28-64 | V | 182.1 | 22.6 | 1.97±.11 | 5.36 | .25 |
| I-6(0041)[b] | 17 y 3 m 12 d | M | 4-28-64 | V | 139.9 | 20.0 | 1.16±.08 | 3.08 | .17 |
| I-6(0041)[b] | 17 y 3 m 12 d | M | 4-28-64 | V | 139.9 | 20.0 | 1.13±.09 | 3.00 | .16 |
| I-6(0044)[b] | 15 y 2 m 4 d | M | 6-26-64 | V | 106.7 | 14.8 | 1.72±.13 | 4.62 | .24 |
| I-6(0044)[b] | 15 y 2 m 4 d | M | 6-26-64 | V | 106.7 | 14.8 | 1.37±.11 | 3.77 | .19 |
| I-6(0046)[b] | 14 y 10 m 17 d | M | 7-17-64 | V | 115.6 | 16.0 | 2.15±.15 | 5.69 | .30 |
| I-6(0046)[b] | 14 y 10 m 17 d | M | 7-17-64 | V | 115.6 | 16.0 | 1.99±.13 | 5.21 | .28 |
| I-6(0048) | 15 y | M | 10-12-64 | V | 221.3 | 27.1 | 1.56±.09 | 4.22 | .19 |
| I-6(0049) | 12 y 8 m | M | 10-11-64 | V | 199.0 | 20.0 | 1.71±.12 | 4.83 | .17 |
| I-6(0051) | 21 y 1 m 25 d | M | 11-26-64 | V | 224.8 | 27.4 | 1.39±.08 | 3.69 | .17 |
| Southeast | | | | | | | | | |
| Maryland | | | | | | | | | |
| III-7(0035) | 7 y 4 m 11 d | M | 5-15-63 | V | 117.3 | 11.7 | .92±.12 | 2.54 | .09 |
| III-7(0041) | 16 y 1 m 27 d | M | 8-1-63 | V | 147.2 | 23.8 | .77±.07 | 2.00 | .12 |
| III-7(0042) | 15 y 1 m 3 d | M | 8-12-63 | V | 166.5 | 23.2 | 1.08±.08 | 2.74 | .15 |
| III-7(0044)[b] | 24 y 8 m 14 d | M | 8-17-63 | V | 108.1 | 19.2 | .88±.08 | 2.27 | .16 |
| III-7(0044)[b] | 24 y 8 m 14 d | M | 8-17-63 | V | 108.1 | 19.2 | .79±.07 | 2.03 | .14 |
| III-7(0045) | 15 y 4 m 17 d | M | 8-18-63 | V | 198.9 | 24.2 | 1.17±.09 | 3.10 | .14 |
| III-7(0046)[a] | 17 y 1 m 27 d | M | 8-17-63 | V | 109.7 | 13.7 | .90±.10 | 2.41 | .11 |
| III-7(0046)[a] | 17 y 1 m 27 d | M | 8-17-63 | V | 109.7 | 13.7 | .90±.10 | 2.40 | .11 |
| III-7(0047) | 21 y 21 d | M | 8-18-63 | V | 142.9 | 19.7 | .84±.08 | 2.19 | .12 |
| III-7(0048) | 22 y 6 m 17 d | M | 8-30-63 | V | 157.0 | 24.0 | .44±.05 | 1.15 | .07 |
| III-7(0051) | 18 y 9 m 8 d | M | 10-27-63 | V | 208.0 | 24.9 | .97±.07 | 2.56 | .12 |
| III-7(0052) | 20 y 21 d | M | 10-27-63 | V | 155.9 | 24.1 | .57±.06 | 1.49 | .09 |
| III-7(0053)[b] | 22 y 4 m 29 d | M | 11-8-63 | V | 89.8 | 14.3 | .84±.10 | 2.17 | .13 |
| III-7(0053)[b] | 22 y 4 m 29 d | M | 11-8-63 | V | 89.8 | 14.3 | .91±.12 | 2.36 | .15 |
| III-7(0054) | 21 y | M | 11-8-63 | V | 87.1 | 13.0 | 1.08±.12 | 2.88 | .08 |
| III-7(0055) | 22 y 3 m 16 d | M | 12-8-63 | V | 185.3 | 21.9 | .87±.08 | 2.32 | .10 |
| III-7(0057)[b] | 22 y 8 m 21 d | F | 9-7-63 | V | 97.7 | 13.8 | .65±.08 | 1.72 | .09 |
| III-7(0058) | 22 y 5 m 15 d | M | 9-2-63 | V | 157.3 | 21.3 | .55±.07 | 1.43 | .07 |
| Eastern Tennessee | | | | | | | | | |
| IV-14(0008) | 12 y 2 m 2 d | M | 2-7-64 | V | 188.0 | 19.8 | 1.82±.12 | 4.94 | .19 |
| Virginia | | | | | | | | | |
| III-5(0004)[b] | 21 y 11 d | M | 6-23-63 | V, R | 122.6 | 19.1 | .42±.06 | 1.10 | .03 |
| III-5(0005) | 5 y 10 m 9 d | F | 7-21-63 | V | 103.0 | 9.9 | 1.34±.15 | 3.50 | .12 |
| Central | | | | | | | | | |
| Minnesota | | | | | | | | | |
| VI-1(0012) | 8 y 5 m 2 d | F | 2-15-64 | V, St | 209.8 | 12.5 | 12.8±.12 | 4.17 | .08 |
| VI-1(0013)[b] | 15 y 11 m | F | 5-14-64 | V | 140.8 | 18.7 | .96±.09 | 2.57 | .06 |
| VI-1(0013)[b] | 5 y 11 m | F | 5-14-64 | V | 140.8 | 18.7 | 1.03±.09 | 2.69 | .14 |
| VI-19(0013)[b] | 22 y 7 m 29 d | F | 5-7-64 | V | 117.1 | 15.6 | .90±.09 | 2.46 | .12 |
| VI-19(0013)[b] | 22 y 7 m 29 d | F | 5-7-64 | V | 117.1 | 15.6 | .90±.10 | 2.14 | .12 |
| VI-19(0016) | 21 y 5 m 10 d | F | 6-1-64 | V | 214.5 | 26.7 | 1.31±.08 | 3.44 | .16 |
| VI-19(0019)[b] | 18 y 2 m 9 d | M | 8-18-64 | V | 121.4 | 19.5 | .94±.08 | 2.41 | .15 |
| VI-19(0021)[b] | 17 y 5 m 17 d | M | 9-10-64 | V | 135.3 | 14.9 | 1.19±.12 | 3.19 | .13 |
| VI-19(0021)[b] | 17 y 5 m 17 d | M | 9-10-64 | V | 135.3 | 14.9 | 1.72±.16 | 4.69 | .19 |
| Missouri | | | | | | | | | |
| VI-4(0001) | 16 y 10 m 4 d | M | 7-24-63 | V | 175.0 | 22.3 | 1.36±.09 | 3.54 | .17 |
| VI-4(0002)[b] | 18 y 6 m | M | 8-17-63 | V | 117.3 | 17.2 | 1.08±.11 | 2.87 | .16 |
| VI-7(0019) | 17 y | F | 3-7-64 | V | 275.7 | 8.3 | .93±.13 | 3.41 | .03 |
| Ohio | | | | | | | | | |
| V-1(0007) | 5 y 5 m 27 d | M | 6-27-63 | V | 146.6 | 10.1 | 1.46±.15 | 4.23 | .10 |
| V-1(0010) | 6 y 2 m 6 d | F | 10-2-63 | V | 151.3 | 16.0 | .94±.10 | 2.56 | .10 |
| V-19(0085) | 6 y 9 d | M | 1-10-63 | V | 116.6 | 11.0 | .83±.12 | 2.25 | .08 |
| V-19(0140) | 5 y 11 m 29 d | F | 10-30-63 | V | 138.3 | 10.9 | 1.79±.17 | 5.28 | .14 |
| V-19(0144) | 3 y 7 m 12 d | F | 9-11-63 | V | 115.0 | 9.1 | 2.02±.21 | 5.56 | .16 |
| V-19(0145) | 4 y 10 m 8 d | F | 10-26-63 | V | 132.7 | 10.0 | 1.81±.17 | 4.87 | .14 |
| V-19(0148) | 7 y | M | 10-2-63 | V | 106.3 | 9.6 | 0.83±.11 | 2.17 | .08 |
| V-19(0153) | 9 y 6 m 20 d | F | 3-21-64 | V | 139.4 | 13.6 | .96±.11 | 2.59 | .09 |
| V-19(0157) | 7 y 6 m 4 d | F | 4-19-64 | V | 218.3 | 15.6 | 1.21±.13 | 3.39 | .09 |
| V-19(0158) | 3 y 11 m 10 d | M | 4-20-64 | V, R | 139.0 | 13.3 | 2.26±.15 | 5.79 | .17 |
| V-19(0196) | 12 y 2 m 29 d | M | 9-13-64 | V | 285.2 | 27.9 | 1.08±.07 | 2.93 | .11 |
| V-19(0199) | 12 y 9 m 13 d | M | 9-26-64 | V | 110.8 | 12.5 | 1.50±.15 | 4.02 | .17 |
| V-19(0205) | 3 y 1 m 21 d | M | 11-3-64 | V | 81.2 | 3.8 | 2.97±.13 | 8.37 | .14 |
| V-25(0001)[b] | 23 y 6 m 15 d | M | 7-29-64 | V | 81.5 | 13.8 | .70±.08 | 1.77 | .12 |
| V-25(0002)[b] | 17 y 25 d | M | 8-19-64 | V, R | 83.8 | 13.5 | .95±.10 | 2.47 | .15 |

## Table 1. Details of samples and results of analysis, October 1964–March 1965—Continued

| Region, state, and sample | Age at death | Sex | Date of death | Bone [a] | Original wt. (g) | Ash wt. (g) | pCi $^{90}Sr$/g of | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ash ±2σ C.E. | Calcium | Bone |
| Central—Continued | | | | | | | | | |
| Wisconsin | | | | | | | | | |
| V-3(0032) | 5 y 5 m 12 d | F | 5-9-63 | V | 121.7 | 12.1 | 1.18±.17 | 3.34 | .12 |
| V-3(0083) | 3 y 2 d | F | 10-23-63 | V | 147.0 | 13.3 | 1.65±.16 | 4.77 | .15 |
| V-3(0133) | 5 y 1 m 26 d | M | 5-25-64 | V | 141.1 | 12.4 | 1.35±.14 | 3.70 | .12 |
| V-3(0138) | 7 y 8 m 9 d | F | 6-12-64 | V | 203.7 | 23.6 | 1.10±.08 | 2.99 | .13 |
| V-3(0175) | 6 y 11 m 5 d | M | 11-25-64 | V | 99.8 | 7.9 | 1.29±.17 | 3.52 | .10 |
| V-3(0177) | 3 y 1 m 29 d | M | 12-14-64 | V | 93.4 | 10.4 | 2.08±.17 | 5.70 | .23 |
| V-3(0178) | 4 y 7 m 16 d | F | 12-16-64 | V | 89.1 | 9.0 | 1.68±.18 | 4.49 | .17 |
| V-3(0180) | 3 y 7 m 7 d | M | 12-17-64 | V | 88.6 | 6.7 | 3.46±.28 | 9.78 | .26 |
| Delta | | | | | | | | | |
| Louisiana | | | | | | | | | |
| VII-6(0003) | 19 y | M | 9-9-64 | V | 120.5 | 21.8 | 1.97±.11 | 5.05 | .36 |
| VII-6(0004) | 17 y 1 m 20 d | M | 9-8-64 | V | 80.7 | 12.7 | 1.15±.11 | 3.06 | .18 |
| VII-8(0021) | 7 y 29 d | F | 2-12-64 | V | 137.5 | 12.7 | 1.91±.19 | 5.33 | .18 |
| VII-8(0022) | 6 y 8 m 11 d | M | 2-4-64 | V | 141.0 | 13.8 | 1.82±.14 | 5.37 | .18 |
| VII-8(0023) | 6 y 2 m | F | 2-21-64 | V, R | 109.2 | 10.7 | .40±.05 | 2.85 | .04 |
| VII-8(0025)[b] | 18 y 10 m 20 d | M | 5-1-64 | V | 94.4 | 13.4 | 1.60±.12 | 4.27 | .23 |
| VII-8(0025)[b] | 18 y 10 m 20 d | M | 5-1-64 | V | 94.4 | 13.4 | 1.09±.11 | 2.83 | .16 |
| VII-8(0026) | 3 y 3 m 23 d | F | 5-2-64 | V | 136.1 | 14.2 | 2.46±.17 | 6.66 | .26 |
| VII-8(0027) | 2 y 29 d | M | 5-2-64 | R | 94.8 | 10.6 | 2.13±.19 | 5.74 | .24 |
| VII-8(0028)[b] | 20 y 10 m 12 d | F | 5-8-64 | V, R | 109.3 | 15.7 | 1.59±.12 | 4.27 | .23 |
| VII-8(0028)[b] | 20 y 10 m 12 d | F | 5-8-64 | V, R | 109.3 | 15.7 | 1.55±.13 | 4.02 | .22 |
| VII-8(0029)[b] | 19 y 3 m 19 d | F | 5-10-64 | V | 102.9 | 14.1 | 1.33±.13 | 3.55 | .18 |
| VII-8(0029)[b] | 19 y 3 m 19 d | F | 5-10-64 | V, R | 102.9 | 14.1 | 1.64±.13 | 4.40 | .23 |
| VII-8(0031)[b] | 6 y 4 m 19 d | F | 5-26-64 | V | 104.3 | 10.4 | 1.12±.12 | 3.13 | .11 |
| VII-8(0032) | 4 y 6 m 1 d | M | 6-7-64 | V | 130.9 | 13.3 | 1.35±.12 | 3.68 | .14 |
| VII-8(0033)[b] | 17 y 1 m 11 d | F | 6-9-64 | V | 103.8 | 17.7 | 1.40±.11 | 3.61 | .24 |
| VII-8(0033)[b] | 17 y 1 m 11 d | F | 6-9-64 | V | 103.8 | 17.7 | 1.17±.10 | 3.09 | .20 |
| VII-8(0034)[b] | 16 y 5 m 15 d | M | 9-27-64 | V, R | 115.2 | 14.8 | 1.54±.12 | 4.37 | .21 |
| VII-8(0035)[b] | 24 y 7 m 21 d | F | 9-27-64 | V, R | 94.2 | 16.2 | .91±.10 | 2.43 | .16 |
| VII-8(0035)[b] | 24 y 7 m 21 d | F | 9-27-64 | V, R | 94.2 | 16.2 | .72±.09 | 1.88 | .12 |
| Western Tennessee | | | | | | | | | |
| IV-9(0016) | 17 y | M | 1-10-64 | V | 135.3 | 21.6 | 0.77±.07 | 2.02 | .12 |
| IV-9(0017) | 11 y | M | 3-9-64 | V | 97.8 | 11.8 | 1.07±.12 | 2.88 | .13 |
| IV-9(0019) | 19 y 2 m | M | 3-14-64 | V | 76.9 | 10.7 | 1.34±.14 | 3.54 | .19 |
| IV-9(0020) | 14 y 1 m 21 d | M | 3-28-64 | V | 135.3 | 16.7 | 1.08±.11 | 2.89 | .13 |
| IV-9(0021) | 16 y 11 m 5 d | F | 4-7-64 | V | 86.7 | 13.9 | 1.11±.10 | 2.91 | .18 |
| Southwest | | | | | | | | | |
| Arizona | | | | | | | | | |
| IX-27(0002) | 5 y 7 m 25 d | F | 3-29-64 | V | 123.9 | 10.4 | .93±.14 | 2.50 | .08 |
| California | | | | | | | | | |
| IX-8(0023) | 6 y 13 d | M | 2-17-64 | V | 117.4 | 11.3 | .76±.11 | 2.11 | .07 |
| IX-8(0024) | 1 y 21 d | M | 3-11-64 | V | 65.0 | 5.1 | 1.14±.10 | 3.21 | .09 |
| IX-8(0026) | 3 y 6 d | F | 9-21-64 | V, R, St | 168.2 | 14.6 | .95±.10 | 2.68 | .08 |
| IX-8(0027) | 2 d | F | 10-8-64 | V, R, LB | 173.0 | 14.2 | .47±.08 | 1.29 | .04 |
| IX-8(0028) | 1 d | F | 10-16-64 | V, R, LB | 224.0 | 25.8 | .39±.05 | 1.04 | .05 |
| IX-8(0029)[b] | 1 d | F | 10-26-64 | V, R, St, LB | 195.5 | 19.6 | .71±.08 | 2.06 | .07 |
| IX-8(0029)[b] | 1 d | F | 10-26-64 | V, R, St, LB | 195.5 | 19.6 | .64±.06 | 1.75 | .06 |
| IX-8(0030) | 1 m 20 d | M | 11-18-64 | V, LB | 195.5 | 19.3 | .56±.06 | 1.51 | .06 |
| IX-9(0011)[b] | 23 y 1 m 5 d | M | 3-13-63 | V | 156.3 | 19.8 | 0.35±.06 | 0.95 | .05 |
| IX-9(0011)[b] | 23 y 1 m 5 d | M | 3-13-63 | V | 156.3 | 19.8 | 0.24±.05 | 0.64 | .03 |
| IX-15(0004) | 6 y 21 d | M | 4-14-64 | V | 135.7 | 10.6 | 1.19±.14 | 3.37 | .09 |
| IX-15(0005) | 1 y 9 d | M | 5-2-64 | V | 61.3 | 8.5 | 1.01±.15 | 2.68 | .14 |
| IX-15(0007) | 17 y | F | 11-30-64 | V | 303.1 | 44.2 | .65±.04 | 1.90 | .10 |
| IX-15(0008) | 3 y 2 m | F | 11-30-64 | V | 44.3 | 6.3 | 1.82±.23 | 5.18 | .26 |
| IX-21(0001) | 14 y 3 m 9 d | M | 12-20-63 | V | 158.3 | 20.5 | 0.68±.08 | 1.87 | .09 |
| IX-25(0001) | 22 y 4 m 21 d | M | 2-12-64 | V, I | 158.5 | 26.3 | 1.14±.08 | 2.98 | .19 |
| IX-25(0005) | 13 y 3 m 9 d | M | 5-5-64 | V | 149.6 | 17.2 | .64±.07 | 1.74 | .07 |
| IX-25(0007) | 1 y 10 m 19 d | M | 5-25-64 | V, I | 129.5 | 12.2 | 1.47±.12 | 4.03 | .14 |
| IX-25(0008) | 1 y 10 m 20 d | M | 6-8-64 | V, I | 128.6 | 9.7 | 1.26±.14 | 3.64 | .10 |
| IX-25(0010) | 5 y 6 m 10 d | M | 6-23-64 | V | 132.5 | 9.7 | .83±.12 | 2.44 | .06 |
| IX-25(0011) | 5 y 4 m 20 d | F | 6-24-64 | V | 172.0 | 15.4 | 0.89±.10 | 2.38 | .08 |
| IX-25(0012) | 17 y 8 m 21 d | M | 7-12-64 | V | 192.6 | 25.5 | 0.72±.06 | 1.95 | .10 |
| IX-25(0013)[b] | 21 y 11 m 21 d | F | 8-25-64 | V | 116.5 | 15.0 | 0.80±.09 | 2.19 | .10 |
| IX-25(0013)[b] | 21 y 11 m 21 d | F | 8-25-64 | V | 116.5 | 15.0 | .68±.08 | 1.82 | .09 |
| IX-25(0014) | 3 y 7 m 1 d | M | 9-13-64 | V | 140.7 | 11.9 | 1.61±.15 | 4.16 | .13 |
| IX-25(0015) | 22 y 29 d | F | 9-28-64 | V | 143.9 | 19.0 | 1.06±.08 | 2.91 | .14 |
| IX-25(0016) | 12 y 8 m 14 d | M | 9-19-64 | V | 118.5 | 12.5 | 1.23±.13 | 3.37 | .13 |
| IX-32(0001) | 22 y 7 m 23 d | F | 2-15-64 | V | 93.6 | 10.4 | .71±.11 | 1.87 | .08 |

**Table 1. Details of samples and results of analysis, October 1964–March 1965—Continued**

| Region, state, and sample | Age at death | Sex | Date of death | Bone [a] | Original wt. (g) | Ash wt. (g) | pCi $Sr^{90}$/g of | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ash ±2σ C.E. | Calcium | Bone |
| Northwest | | | | | | | | | |
| Alaska | | | | | | | | | |
| IX-34(0001) | 22 y 9 m 28 d | F | [d]10-20-64 | R | 15.2 | 4.6 | 1.47±.05 | 3.91 | .45 |
| IX-34(0006) | 20 y | M | [d]9-30-64 | R | 16.1 | 5.8 | 0.98±.05 | 2.62 | .35 |
| IX-13(0001)[b] | 16 y 6 m 14 d | M | 5-20-63 | V | 114.4 | 16.5 | 0.86±.09 | 2.50 | .12 |
| IX-13(0004) | 18 y 8 m | M | 8-21-63 | V | 213.8 | 25.9 | 0.16±.06 | 1.64 | .07 |
| IX-13(0006)[b] | 16 y 5 m 11 d | M | 1-17-64 | V | 100.8 | 14.2 | 2.32±.15 | 6.05 | .33 |
| IX-13(0006)[b] | 16 y 5 m 11 d | M | 1-17-64 | V | 100.8 | 14.2 | 3.06±.22 | 7.95 | .43 |
| IX-18(0001) | 8 y 7 m | F | 1-24-64 | I | 182.1 | 18.2 | 1.59±.11 | 4.31 | .16 |
| Washington | | | | | | | | | |
| IX-7(0018) | 10 y 7 m 22 d | M | 3-13-63 | V | 144.7 | 18.9 | .60±.07 | 2.20 | .08 |
| IX-7(0026) | 9 y 3 m 27 d | M | 3-19-64 | V | 59.1 | 6.0 | 1.93±.22 | 5.16 | .20 |
| IX-7(0027) | 16 y 10 m 10 d | F | 6-10-64 | V | 96.8 | 16.9 | 1.06±.09 | 2.73 | .19 |
| IX-7(0028) | 12 y 11 m 23 d | M | 8-30-64 | V | 157.2 | 16.7 | 2.09±.15 | 5.61 | .22 |
| IX-13(0002) | 17 y 3 m 25 d | M | 6-13-63 | V | 180.2 | 21.3 | .79±.07 | 2.09 | .09 |
| IX-13(0003) | 17 y 10 m 24 d | M | 6-13-63 | V | 160.7 | 20.5 | .62±.06 | 1.62 | .08 |
| Other | | | | | | | | | |
| Colorado | | | | | | | | | |
| VIII-4(0001) | 13 y 2 m 23 d | F | 10-12-62 | V | 151.4 | 21.5 | 0.50±.06 | 1.30 | .07 |
| VIII-4(0003)[b] | 10 y 11 m 14 d | M | 6-24-64 | V | 101.8 | 20.4 | 0.76±.07 | 1.95 | .15 |
| VIII-4(0003)[b] | 10 y 11 m 14 d | M | 6-24-64 | V | 101.8 | 20.4 | 0.67±.07 | 1.72 | .14 |
| Texas | | | | | | | | | |
| VII-11(0002)[b] | 13 y | M | [d]3-63 | F | 118.5 | 16.9 | 0.44±.07 | 1.11 | .03 |
| Utah | | | | | | | | | |
| VIII-1(0001) | 6 y 28 d | M | 12-5-62 | V, R | 115.6 | 12.1 | 0.75±.10 | 2.03 | .08 |

[a] V, vertebra; R, rib; I, ilium; St, sternum; F, femur; LB, long bones.
[b] Blind duplicate—sample split and submitted on different dates for analysis.
[c] Duplicate analysis.
[d] Sample obtained by surgical procedure.

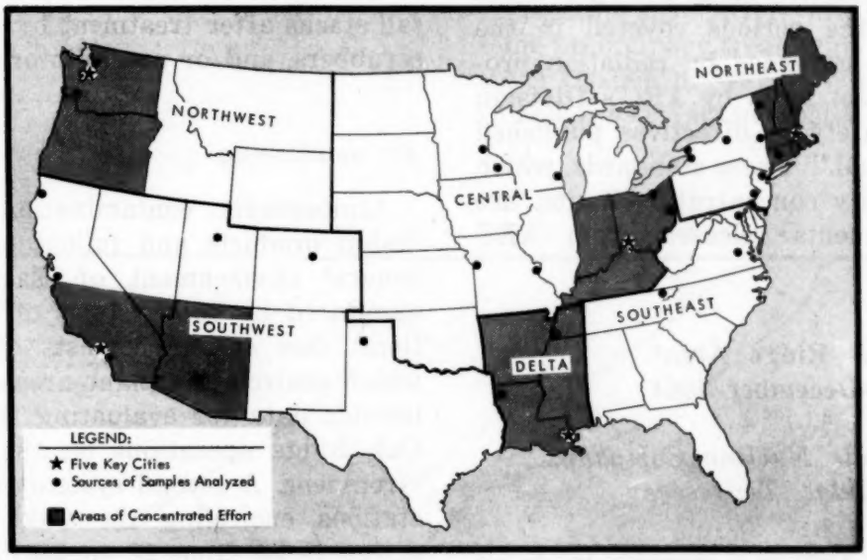


**Figure 1. Regions for PHS bone sampling network and sources of samples analyzed, October 1964–March 1965**

subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2*, *4*).

## REFERENCES


(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Rad Health Data 5: 511–513 (October 1964).

(*2*) WEISS, E. W., W. H. LAND, K. H. FALTER, and R. M. Hallisey. Strontium-90 content of human bones (1961–1963). Rad Health Data 5:231–239 (May 1964).

(*3*) NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY, PUBLIC HEALTH SERVICE. Analysis of environmental, samples chemical and radiochemical procedures. NERHL 64–1 (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone. Rad Health Data 5:620–628 (December 1964).

# ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semi-annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Oak Ridge Area, Paducah Plant and Portsmouth Area Gaseous Diffusion Plant.

Releases of radioactive materials from these installations for the periods covered in the reports below are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1] These standards, which include radioactivity concentration limits, are applicable to effluents released from AEC installations.

## 1. Oak Ridge Area[2] July–December 1964

*Union Carbide Nuclear Company, Oak Ridge, Tennessee*

The Oak Ridge Area is a complex made up primarily of the Y–12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge Area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ion exchange activity that enables it to fix radioactive materials. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches located in the Conasauga shale formation. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

### *Air monitoring*

Atmospheric contamination by long-lived fission products and fallout occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of eight stations which encircle the plant areas (figure 1) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of seven stations encircling the Oak Ridge Area at distances of from 12 to 75 miles (figure 2). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average concentrations are presented in table 1. Airborne radioactive iodine is monitored in the immediate environment of plant areas by passing air through a cartridge containing activated charcoal.

[1] Part 20, "Standards for Protection Against Radiation," AEC Rules and Regulations, contains essentially the standards published in the AEC Manual. AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, on a subscription basis at $3.50 for 3 years.

[2] Summarized from Environmental Levels of Radioactivity for the Oak Ridge Area, compiled by the Applied Health Physics Section of the Health Physics Division, Oak Ridge National Laboratory.

**Table 1. Long-lived gross beta concentrations in air, Oak Ridge area, average concentrations in pCi/m³**

| Perimeter stations (see figure 1) | Number of samples | Second half 1964 | Remote stations (see figure 2) | Number of samples | Second half 1964 |
|---|---|---|---|---|---|
| HP-31 | 26 | 0.36 | HP-51 | 26 | 0.45 |
| HP-32 | 26 | 0.53 | HP-52 | 25 | 0.47 |
| HP-33 | 26 | 0.31 | HP-53 | 26 | 0.50 |
| HP-34 | 26 | 0.35 | HP-54 | 26 | 0.53 |
| HP-35 | 26 | 0.42 | HP-55 | 26 | 0.45 |
| HP-36 | 186 | 0.43 | HP-56 | 26 | 0.38 |
| HP-37 | 26 | 0.37 | HP-57 | 26 | 0.41 |
| HP-38 | 23 | 0.35 | | | |
| Average | | 0.39 | Average | | 0.46 |

Atmospheric contamination by uranium is determined by gross alpha measurements of continuous air samples taken at five locations within a five-mile radius from the ORGDP (figure 1). The data are summarized in table 2.

**Table 2. Long-lived gross alpha activity in air[a] five miles from ORGDP, average concentrations in pCi/m³**

| Direction from plant | Second half 1964 |
|---|---|
| North | 0.15 |
| Northeast | 0.16 |
| Southwest | 0.15 |

[a] Interpreted as uranium (natural)

### *Milk monitoring*

Raw milk is monitored for iodine–131 and strontium–90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge Area. Four stations, remotely located with respect to Oak Ridge Operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge Area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples.

### *Water monitoring*

Large volume, low-level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River System by way of White Oak Creek and Clinch River. Liquid wastes originating at the

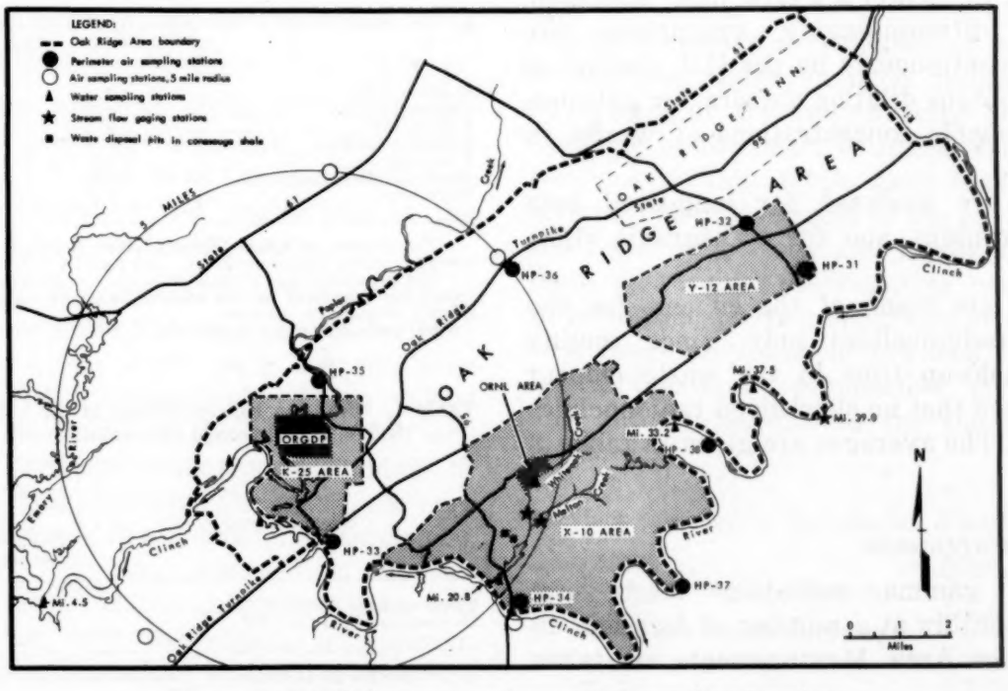


**Figure 1. Oak Ridge area environmental sampling locations**

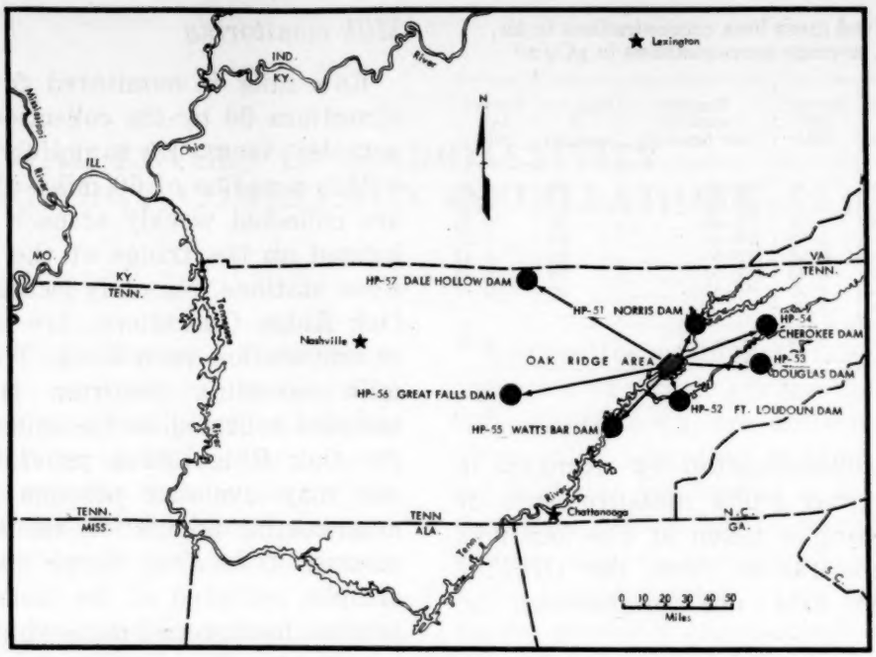


**Figure 2. Remote air monitoring stations, Oak Ridge area**

ORGDP and Y–12 Plant are discharged to Poplar Creek and thence to the Clinch River. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tennessee. Stream-gaging operations are carried on continuously by the U.S. Geological Survey to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for long-lived beta emitters, uranium, and for transuranic alpha emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold-up time in the waste effluent system is such that no short-lived radionuclides are present. The averages are given in tables 3 and 4.

*Gamma measurements*

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge Area. Measurements are taken with Geiger-Mueller tube at a distance of 3 feet above ground, and the results are shown in table 5 in terms of mR/hr.

**Table 3. Concentrations of major radionuclides in the Clinch River, average concentrations in pCi/liter**

| Radionuclide | Second half 1964 | | |
|---|---|---|---|
| | Location on Clinch River [a] | | |
| | Mile 41.5 (Upstream) | Mile 20.8 [b] (Outfall) | Mile 4.5 (Downstream) |
| Strontium-90 | 0.9 | 0.9 | 1.9 |
| Cerium-144 | 0.4 | <0.1 | 0.6 |
| Cesium-137 | 0.2 | 0.4 | 0.25 |
| Ruthenium-106 | 2.0 | 17 | 13 |
| Cobalt-60 | [c] ND | 2.1 | 2.1 |
| Zirconium-60—niobium-95 | [c] ND | <0.1 | [c] ND |
| Gross beta | 3.5 | 3.1 | 20 |

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.
[b] The concentrations at mile 20.8 are not measured directly but the values are calculated on the basis of levels of waste released and the dilution afforded by the river.
[c] ND indicates none was detected.

**Table 4. Uranium concentrations in the Clinch River, Oak Ridge Area, average concentrations in pCi/liter**

| Sampling location | Second half 1964 | |
|---|---|---|
| | Number of samples [a] | Uranium concentration |
| Upstream from ORGDP | 4 | 1.0 |
| Downstream from ORGDP | 4 | 1.0 |

[a] Normal sampling frequency is continuous, composited over one week.

**Table 5. External gamma radiation levels, Oak Ridge area, average exposure rates in mR/hr**

| Location | Exposure rates second half 1964 (mR/hr) |
|---|---|
| Solway Gate | 0.014 |
| Y-12 East Portal | 0.012 |
| Newcomb Road | 0.013 |
| Gallaher Gate | 0.015 |
| White Wing Gate | 0.014 |
| Average | 0.013 |

*Discussion of data*

The average air contamination levels for gross beta activity, as shown by the continuous air-monitoring filter data for the immediate and remote environs of the plants, were 0.39 percent and 0.46 percent, respectively, of the maximum permissible concentration for populations in the neighborhood of a controlled area. These values are approximately 70 percent lower than those of the first half of 1964 and are no higher than the average of those measured in other areas of the United States and reported by the U.S. Public Health Service Radiation Surveillance Network for the period July through October, 1964.

The average concentration of iodine–131 in air in the immediate environs of the plants were 0.018 pCi/m$^3$. This is approximately 0.018 percent of the maximum permissible concentration for population in the neighborhood of a controlled area.

The average airborne alpha activity in the environs of the ORGDP, five miles from ORGDP, was 7.5 percent of the maximum permissible concentration for populations in the neighborhood of a controlled area.

The average concentration of iodine–131 in raw milk in the immediate and remote environs of the Oak Ridge Area were 7.0 pCi/liter and 5.4 pCi/liter, respectively. These values fall within the limits of FRC Range I if one assumes the average intake per individual to be 1 liter of milk per day. The maximum concentration observed in any one milk sample was 72 pCi/liter. This was observed in the immediate environs of the controlled area and was associated with the release of approximately 1,200 millicuries of iodine–131 from the plant stacks during a period of one week.

The average concentrations of strontium–90 in raw milk collected in the immediate and remote environs of the controlled area were 20 pCi/liter and 19 pCi/liter, respectively. These values approach the lower limit of FRC Range II for transient rates of daily intake of strontium–90 for application to the average of suitable samples of an exposed population.

The calculated average concentration of radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and measured average concentration at mile 4.5 (near Kingston, Tennessee) were 31 pCi/liter and 20 pCi/liter, respectively. These values are 0.65 percent and 0.8 percent of the respective weighted average maximum permissible concentrations $(MPC)_w$. The average concentration of transuranic alpha emitters in the Clinch River at mile 20.8 was 0.009 pCi/liter, which is $<0.001$ percent of the weighted average $(MPC)_w$ values.

The average activity of natural uranium materials in the Clinch River, reflecting the effects of all Oak Ridge plants, was $<0.01$ percent of the $(MPC)_w$ for uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge Area averaged 0.013 mR/hr.

*Conclusion*

Comprehensive surveillance of radioactivity in the Oak Ridge environs indicated that a large part of the radioactivity detected continues to be the result of fallout from previous weapons testing. While some low-level radioactivity is being released to the environment in the form of gaseous and liquid wastes from plant operations, the resulting concentrations in both atmosphere and surface streams of the Oak Ridge environment are well below established maximum permissible concentrations and daily intake-guides for the neighboring population.

Previous coverage in *Radiological Health Data:*

| *Period* | *Issue* |
|---|---|
| First and second quarters 1961 | *January 1962* |
| Third and fourth quarters 1961 | *September 1962* |
| 1962 | *September 1963* |
| 1963 | *July 1964* |
| January–June 1964 | *January 1965* |

## 2. Paducah Plant, Calendar Year 1964

*Union Carbide Nuclear Company*
*Paducah, Kentucky*

The Paducah Plant is a Government-owned gaseous diffusion plant operated by Union Carbide Corporation, Nuclear Division for the Atomic Energy Commission. The diffusion plant, with the associated uranium hexafluoride manufacturing plant and uranium metal foundry, processes large quantities of relatively pure uranium compounds. The major sources of external penetrating radiation are the daughter products of uranium, thorium–234, and protactinium–234, which may be concentrated by uranium recovery processes or uranium hexafluoride vaporization. The element, uranium, can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Uranium is a rather expensive element, and this provides a great incentive to recover as much in any situation as is feasible. The added desire to maintain a wholesome relationship with neighboring communities and individuals makes it essential that entrained dust be filtered from exhaust systems, and that all effluent waters be maintained at extremely low concentrations of uranium.

Since no recovery process or filtering system is 100 percent efficient, an environmental monitoring program is required to evaluate the effectiveness of such measures. The Paducah Plant environmental monitoring program provides for continuous air sampling at 4 stations around the plant perimeter fence, and at 5 stations located approximately 1 mile outside this fence. Sampling stations which were operated 5 miles outside the fence for the first half of 1964 were discontinued. Big Bayou Creek water is sampled continuously, and grab samples are collected at 5 locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

### *Basic standards*

The standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for off-site exposure of the general population, are those listed in the AEC Manual (see footnote on page 391).

The standards specify that "radiation or radioactive materials outside a controlled area, and which have resulted from operations within the controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year." To meet this standard, the average concentration of radioisotopes in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

### *Discussion of data*

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 6 through 10.

**Table 6. Outdoor uranium air samples, Paducah Plant, 1964**

| Sample location [a] | Number of samples | Uranium alpha,[b] (pCi/m³) | | | Mean as percent of concentration limit [d] |
|---|---|---|---|---|---|
| | | Maximum | Minimum [c] | Mean | |
| AT PLANT PERIMETER FENCE | | | | | |
| N | 52 | 0.32 | <0.02 | 0.048 | 2.4 |
| E | 52 | 0.41 | <0.02 | 0.046 | 2.3 |
| S | 52 | 0.20 | <0.02 | 0.033 | 1.7 |
| W | 52 | 0.26 | <0.02 | 0.029 | 1.5 |
| Totals | 208 | 0.41 | <0.02 | 0.040 | 2.0 |
| ABOUT ONE MILE OUTSIDE PLANT PERIMETER FENCE | | | | | |
| N | 52 | 0.19 | <0.02 | 0.026 | 1.3 |
| E | 52 | 0.21 | <0.02 | 0.033 | 1.7 |
| S | 52 | 0.34 | <0.02 | 0.037 | 1.9 |
| W | 52 | 0.31 | <0.02 | 0.024 | 1.2 |
| SE | 52 | 0.37 | <0.02 | 0.037 | 1.9 |
| Totals | 260 | 0.37 | <0.02 | 0.031 | 1.6 |
| ABOUT FIVE MILES OUTSIDE PLANT PERIMETER FENCE | | | | | |
| SW | 26 | 0.03 | <0.02 | 0.011 | 0.6 |
| NW | 26 | 0.13 | <0.02 | 0.023 | 1.2 |
| NE | 26 | 0.12 | <0.02 | 0.024 | 1.2 |
| SE | 26 | 0.07 | <0.02 | 0.019 | 1.0 |
| Totals | 104 | 0.13 | <0.02 | 0.019 | 1.0 |

[a] See map in figure 3.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to $7.57 \times 10^4$ alpha dis/sec.
[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.
[d] The concentration limit for natural uranium in air released to the environs is 2 pCi/m³.

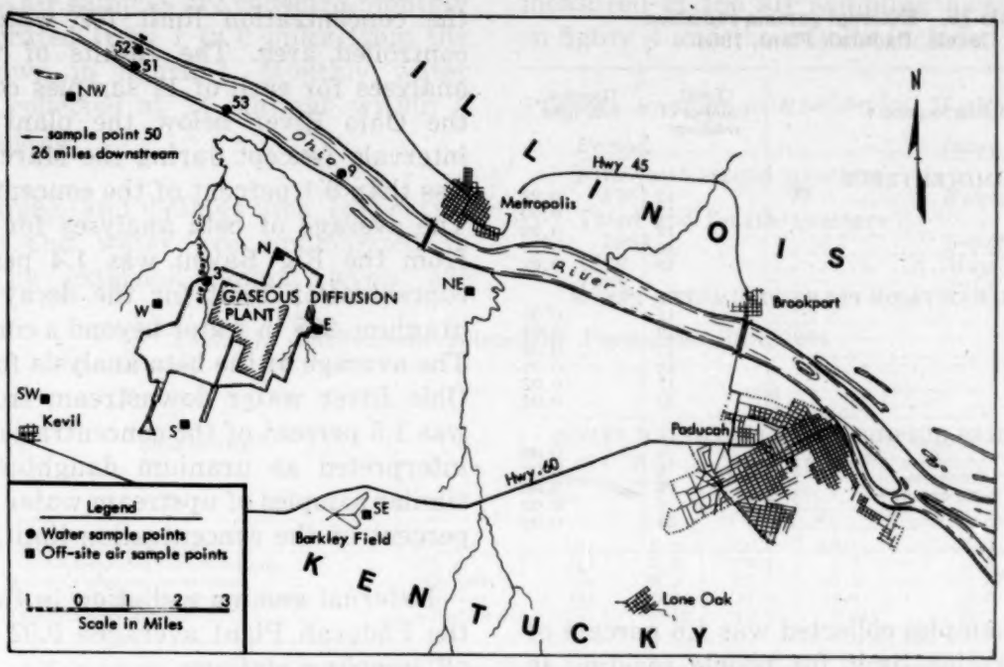


**Figure 3. Water sampling locations, Paducah Gaseous Diffusion Plant**

**Table 7. Outdoor beta air samples, Paducah Plant, 1964**

| Sample location [a] | Number of samples | Beta (pCi/m³) | | | Mean as percent of concentration limit [c] |
|---|---|---|---|---|---|
| | | Maximum | Minimum [b] | Mean | |
| AT PLANT PERIMETER FENCE | | | | | |
| N | 52 | 11 | 0.4 | 2.3 | 0.2 |
| E | 52 | 6 | 0.4 | 1.8 | 0.2 |
| S | 52 | 3 | <0.1 | 0.9 | 0.09 |
| W | 52 | 5 | 0.4 | 0.9 | 0.09 |
| Totals | 208 | 11 | <0.1 | 1.4 | 0.1 |
| ABOUT ONE MILE OUTSIDE PLANT PERIMETER FENCE | | | | | |
| N | 52 | 3 | 0.4 | 0.9 | 0.09 |
| E | 52 | 3 | 0.4 | 0.9 | 0.09 |
| S | 52 | 3 | 0.4 | 0.9 | 0.09 |
| W | 52 | 3 | 0.4 | 0.9 | 0.09 |
| SE | 52 | 3 | 0.4 | 0.9 | 0.09 |
| Totals | 260 | 3 | 0.4 | 0.9 | 0.09 |
| ABOUT FIVE MILES OUTSIDE PLANT PERIMETER FENCE | | | | | |
| SW | 26 | 2 | 0.4 | 1.2 | 0.1 |
| NW | 25 | 3 | 0.9 | 1.5 | 0.2 |
| NE | 26 | 3 | 0.4 | 1.5 | 0.2 |
| SE | 26 | 3 | 0.4 | 1.3 | 0.1 |
| Totals | 104 | 3 | 0.4 | 1.4 | 0.1 |

[a] See map in figure 3.
[b] The minimum detectable amount of beta emitters in air is 0.1 pCi/m³.
[c] The concentration limit applicable to this table is 1,000 pCi/m³, which is the concentration limit thorium-234, the daughter product of $^{238}U$. Insignificant amounts of other daughters are present in freshly refined uranium.

**Air samples were collected continuously at each of 4 stations at the plant perimeter fence, at 5 stations at about 1 mile outside the plant, and at 4 stations located about 5 miles from the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta activity.**

**The average alpha count—interpreted as uranium—the most likely source of activity, of**

**Table 8. Concentration of uranium in water, Paducah Plant, 1964**

| Sample location [a] | Number of samples | Uranium [b], pCi/liter | | | Mean as percent of concentration limit [d] |
|---|---|---|---|---|---|
| | | Maximum | Minimum [c] | Mean | |
| Big Bayou Creek 3 | 52 | 59 | <1 | 15 | 0.1 |
| Ohio River 9 | 11 | 1 | <1 | <1 | <0.01 |
| Composite of 50, 51, 52, & 53 | 11 | 2 | <1 | <1 | <0.01 |

[a] See map in figure 3.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to $7.57 \times 10^4$ dis/sec.
[c] The minimum detectable concentration of uranium in water is 1 pCi/liter.
[d] The concentration limit for natural uranium in water beyond a controlled area is 20,000 pCi/liter.

**Table 9. Concentration of beta emitters in water, Paducah Plant, 1964**

| Sample location [a] | Number of samples | Beta emitters, pCi/liter | | | Mean as percent of RCG [c] |
|---|---|---|---|---|---|
| | | Maximum | Minimum [b] | Mean | |
| Big Bayou Creek 3 | 52 | 2100 | <100 | 280 | 1.4 |
| Ohio River 9 | 11 | 700 | <100 | 200 | 1.0 |
| Composite of 50, 51, 52 & 53 | 11 | 1800 | <100 | 400 | 2.0 |

[a] See map in figure 3.
[b] The minimum detectable amount of beta emitters in water is 100 pCi/liter.
[c] The concentration limit for the daughter products of uranium in water released to the environs is 20,000 pCi/liter.

**Table 10. External gamma radiation levels, Paducah Plant, 1964**

| Air sampling location * | Total number of readings | Gamma, mR/hour |
|---|---|---|
| AT PLANT PERIMETER FENCE | | |
| N | 12 | 0.02 |
| E | 12 | 0.02 |
| S | 12 | 0.02 |
| W | 12 | 0.02 |
| Total | 48 | 0.02 |
| ABOUT ONE MILE OUTSIDE PLANT PERIMETER FENCE | | |
| N | 12 | 0.02 |
| E | 12 | 0.02 |
| S | 12 | 0.02 |
| W | 12 | 0.02 |
| SE | 12 | 0.02 |
| Total | 60 | 0.02 |
| ABOUT FIVE MILES OUTSIDE PLANT PERIMETER FENCE | | |
| SW | 6 | 0.02 |
| NW | 6 | 0.02 |
| NE | 6 | 0.02 |
| SE | 6 | 0.02 |
| Total | 24 | 0.02 |

* See map, figure 3.

the 572 air samples collected was 1.6 percent of the concentration limit for people residing in the vicinity of a controlled area.

The mean beta count of the 572 samples was 0.12 percent of the concentration limit for the daughter products of uranium in air beyond a controlled area.

The average of uranium analyses of weekly water samples collected by a continuous water sampler in the Big Bayou was 0.1 percent of the concentration limit for water beyond a controlled area. The results of the uranium analyses for each of 11 samples collected from the Ohio River below the plant at monthly intervals (except during the March flood) was less than 0.1 percent of the concentration limit. The average of beta analyses for the samples from the Big Bayou was 1.4 percent of the concentration limit for the decay products of uranium–238 in water beyond a controlled area. The average of the beta analysis for samples of Ohio River water downstream from the plant was 1.5 percent of the concentration limit when interpreted as uranium daughters. However, similar samples of upstream water averaged 1.5 percent of the concentration limit.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hour at all sampling stations.

Previous coverage in *Radiological Health Data:*

| *Period* | *Issue* |
|---|---|
| First and second quarters 1961 | *January 1962* |
| Third and fourth quarters 1961 | *August 1962* |
| 1962 | *September 1963* |
| 1963 | *July 1964* |
| January–June 1964 | *February 1965* |

## 3. Portsmouth Area Gaseous Diffusion Plant,[3] Calendar Year 1964

*Goodyear Atomic Corporation*
*Piketon, Ohio*

The separation of uranium isotopes by the gaseous diffusion process presents control problems similar to any chemical process using toxic solvents and extraction solutions. Natural uranium and thorium–234 are the most likely radionuclides to be released to the environment by the Portsmouth Area Gaseous Diffusion Plant. Since natural uranium is an alpha emitter and thorium–234 is a beta-gamma emitter, environmental monitoring is conducted for evidence of alpha and beta-gamma emitters to test the effectiveness of plant controls.

[3] Data summarized from B. Kalmon: Environmental Radiation Levels and Concentrations, 1964, GAT–450 (March 1, 1965).

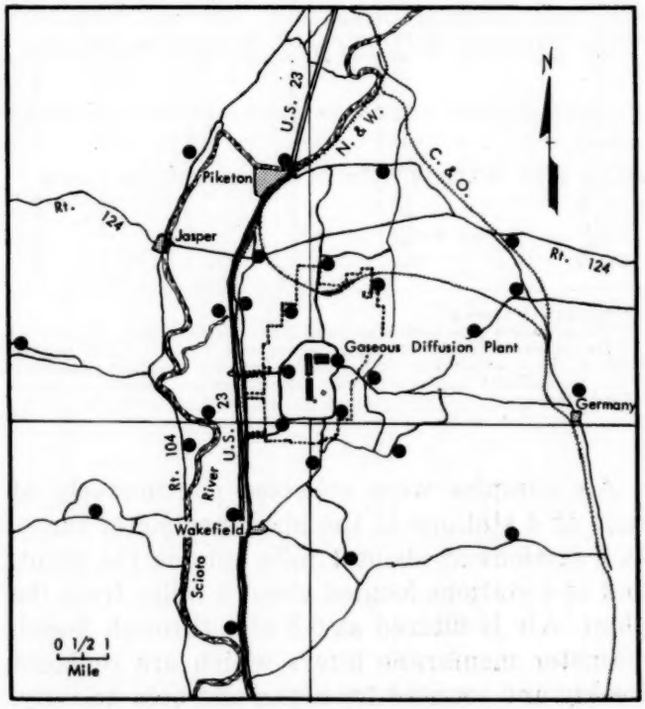


Figure 4. Air sampling locations, Portsmouth Gaseous Diffusion Plant

Continuous air samples are collected monthly at 21 sites located from 1 to 6 miles from the plant as shown in figure 4. Monthly water samples are collected at 14 stations within 5 miles of the plant.

Average alpha and beta-gamma concentrations in air and water are summarized in table 11. The external gamma levels are measured at the air sampling locations shown in figure 4 and the results included in table 11.

Previous coverage in *Radiological Health Data:*

| *Period* | *Issue* |
|---|---|
| First and second quarters 1961 | *February 1962* |
| Third and fourth quarters 1961 | *September 1962* |
| 1962 | *May 1963* |
| 1963 | *July 1964* |

**Table 11. Environment radioactivity, Portsmouth plant, 1964**

| Measurement | Unit | 1964 | | | | |
|---|---|---|---|---|---|---|
| | | No. of samples | Maximum | Minimum | Average | Percent maximum permissible for average |
| Air (alpha concentration) | pCi/m³ | 251 | 0.9 | <0.1 | <0.1 | <5.0 |
| Air (beta-gamma concentration) | pCi/m³ | 251 | 8.5 | <0.1 | 1.5 | 1.5 |
| Water (alpha concentration) | pCi/liter | 150 | 198.2 | <0.5 | 13.5 | 0.07 |
| Water (beta-gamma concentration) | pCi/liter | 144 | 90.2 | <14.0 | 14.0 | 0.07 |
| External beta-gamma [a] | mRad/hr | 251 | 0.12 | <0.01 | 0.04 | 48 |

[a] Measurements were made with open shield Geiger-Mueller tube one foot above ground. The three-foot rate (not shown) was experimentally determined to average two-thirds of the one-foot rate.

## REPORTED NUCLEAR DETONATIONS, JUNE 1965

During June 1965 two United States nuclear tests were announced by the Atomic Energy Commission. The tests conducted underground at the Commission's Nevada Test Site on June 11 and June 16, 1965, were each of low yield (less than 20 kilotons).